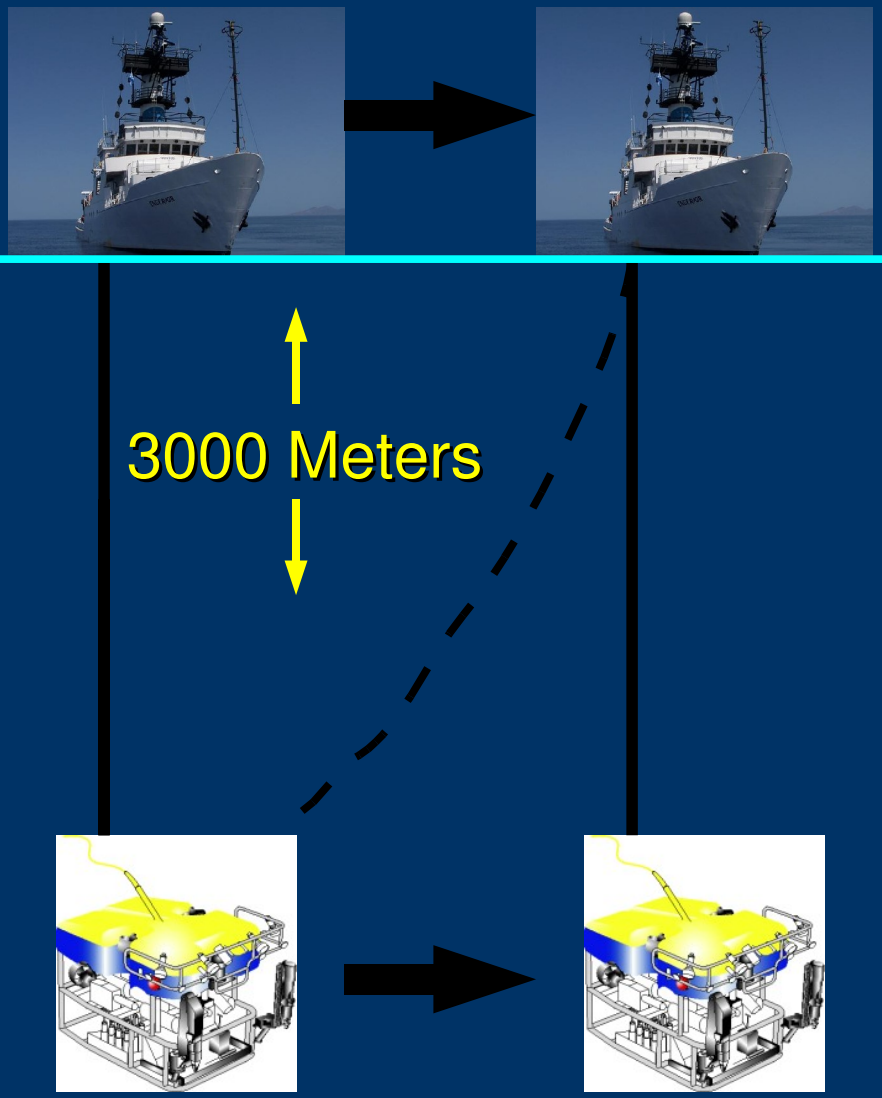
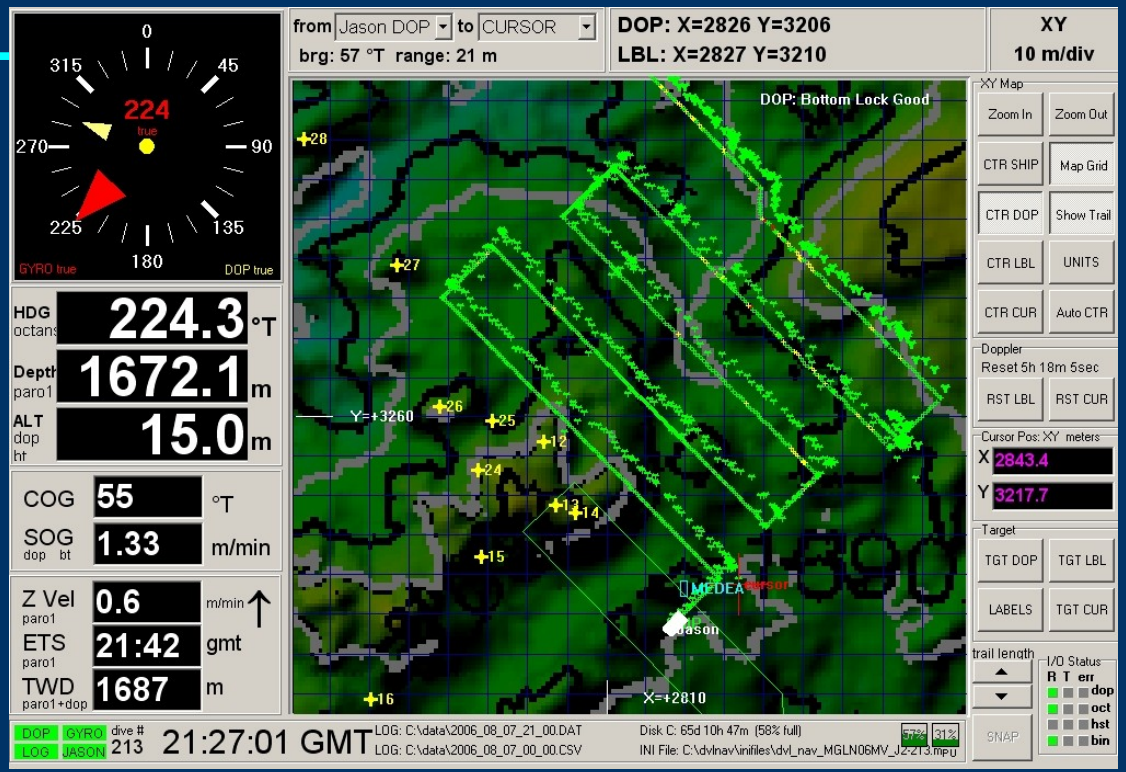
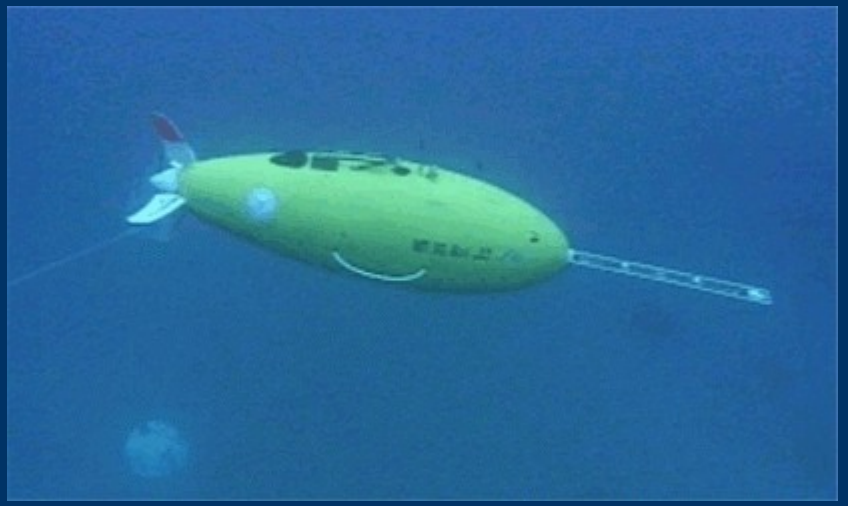
Moving the ship and ROVs

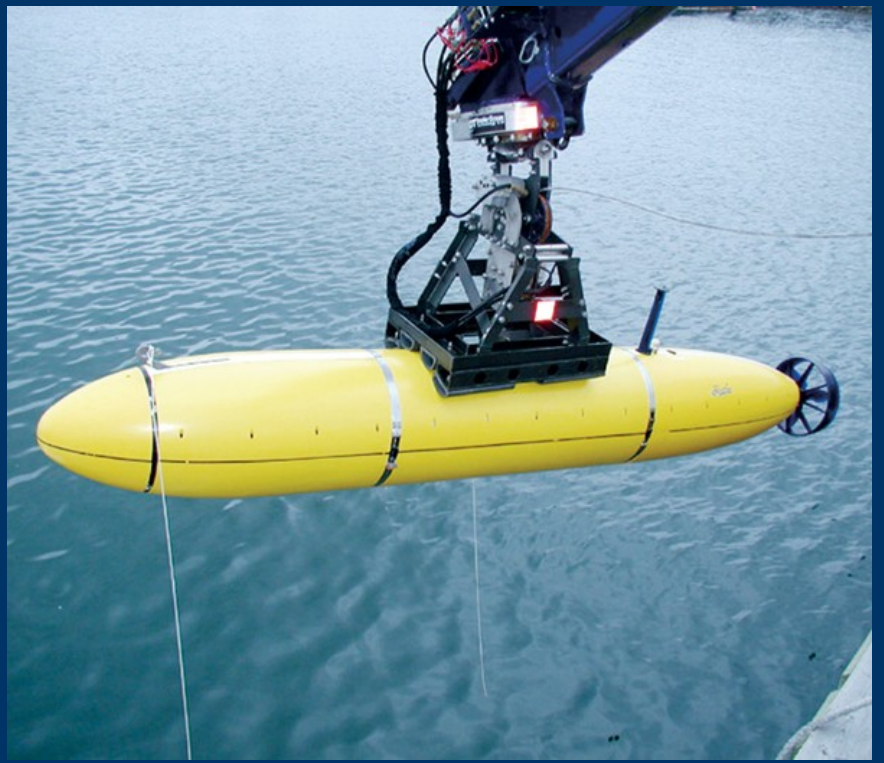




AUVs

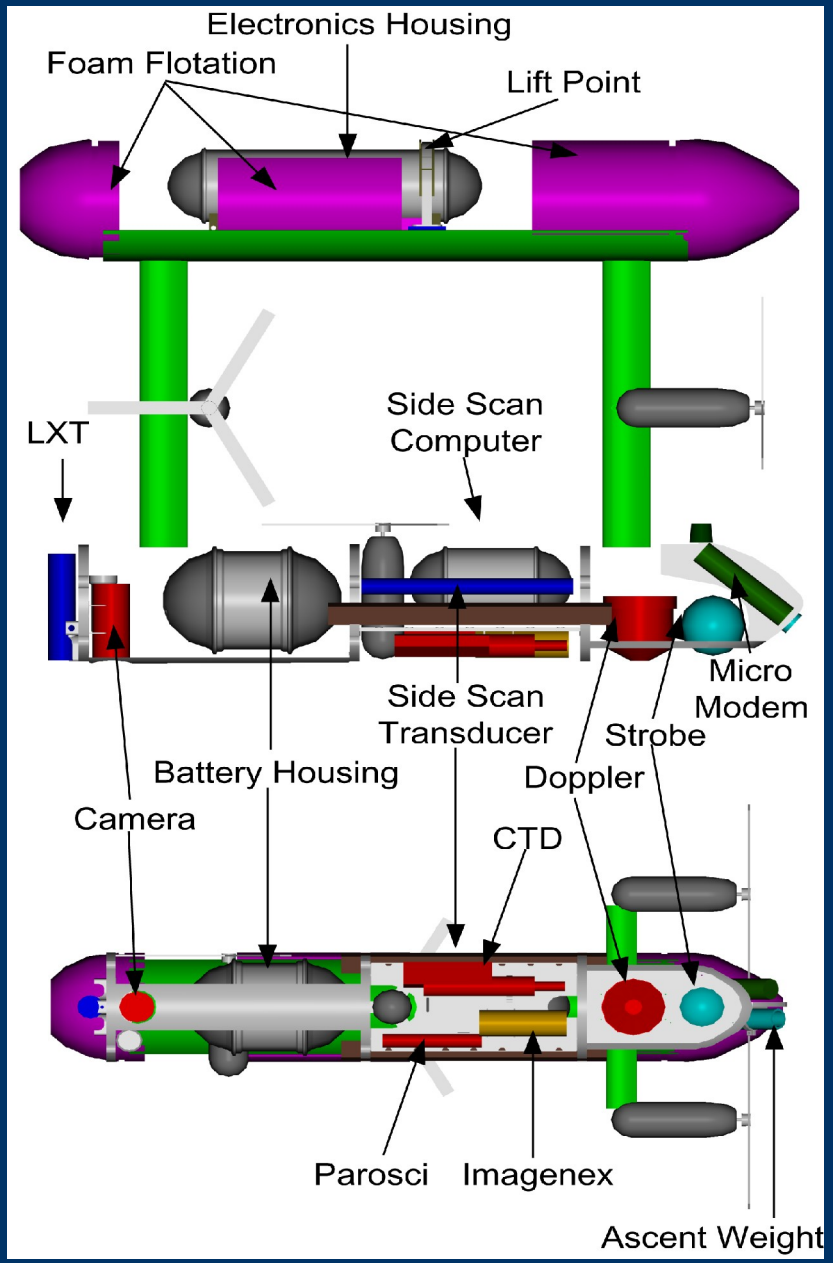


HUGIN 3000 Autonomous Underwater Vehicle (AUV)



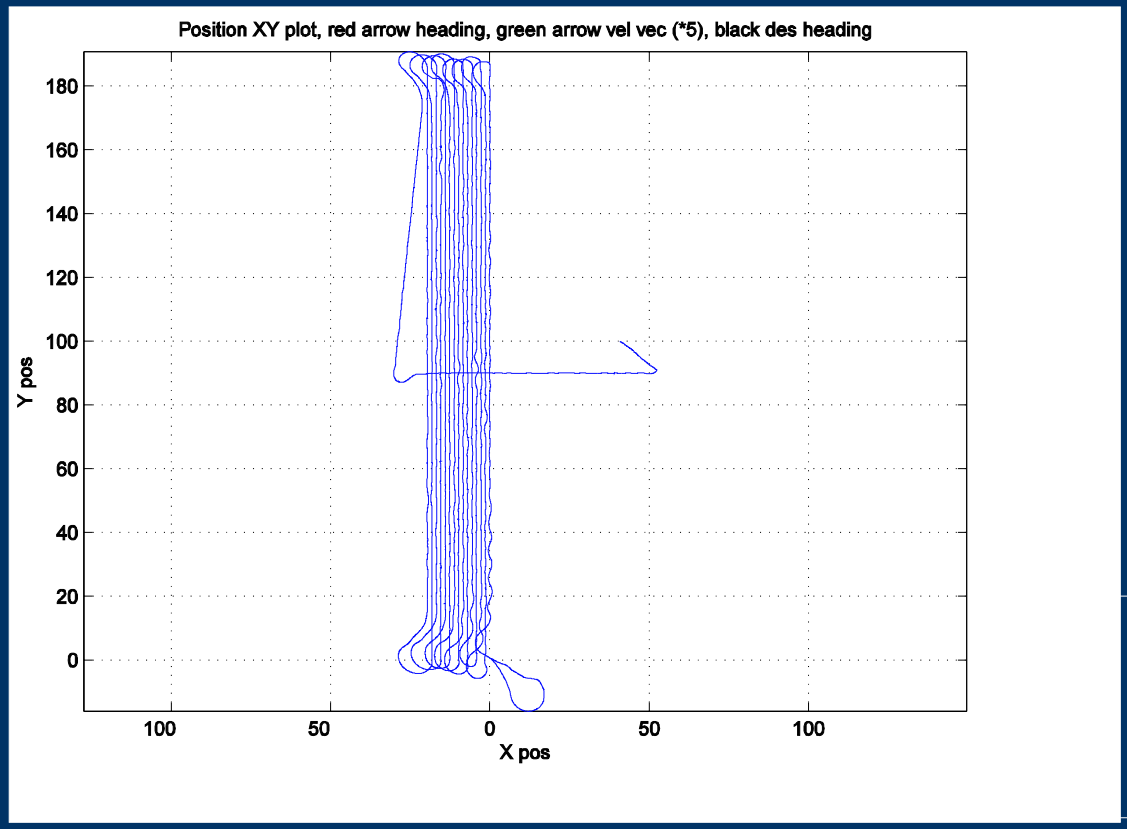
AUV stuff

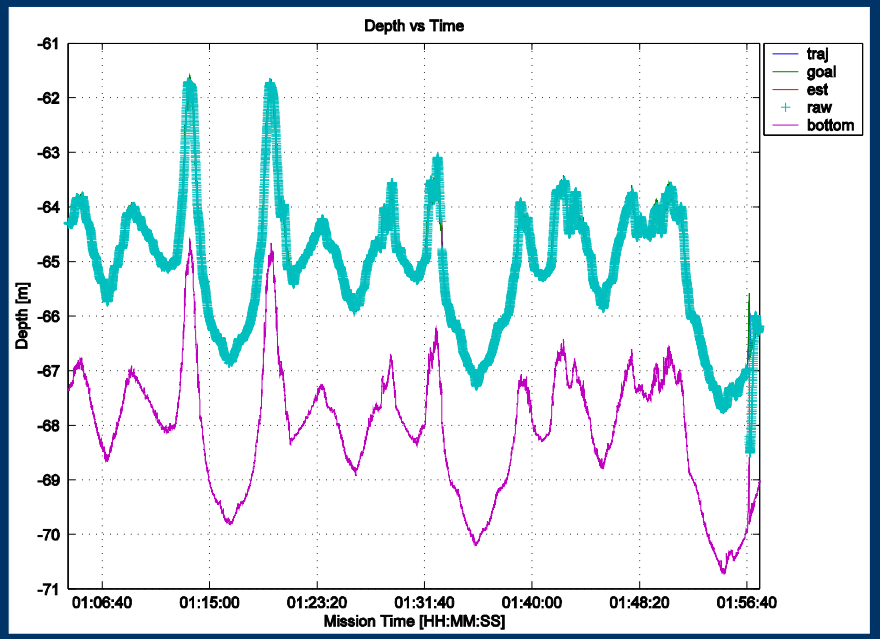

'02 3 6

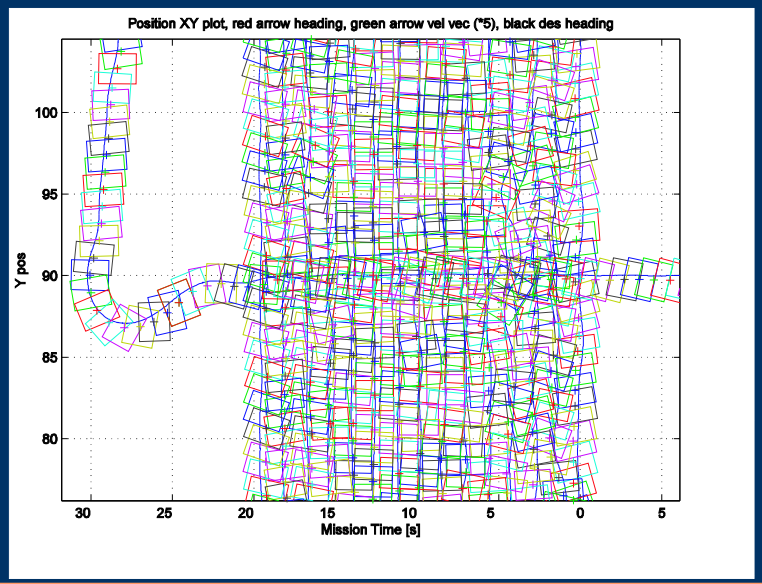

Electronics Housing
Foam Flotation
Lift Point
LXT
Side Scan
Computer
Micro
Modem
Side Scan
Transducer
Strobe
Doppler
Battery Housing
Camera
CTD
Parosci
Imagenex
Ascent Weight

Typical AUV survey data

- Good for surveys and bottom following

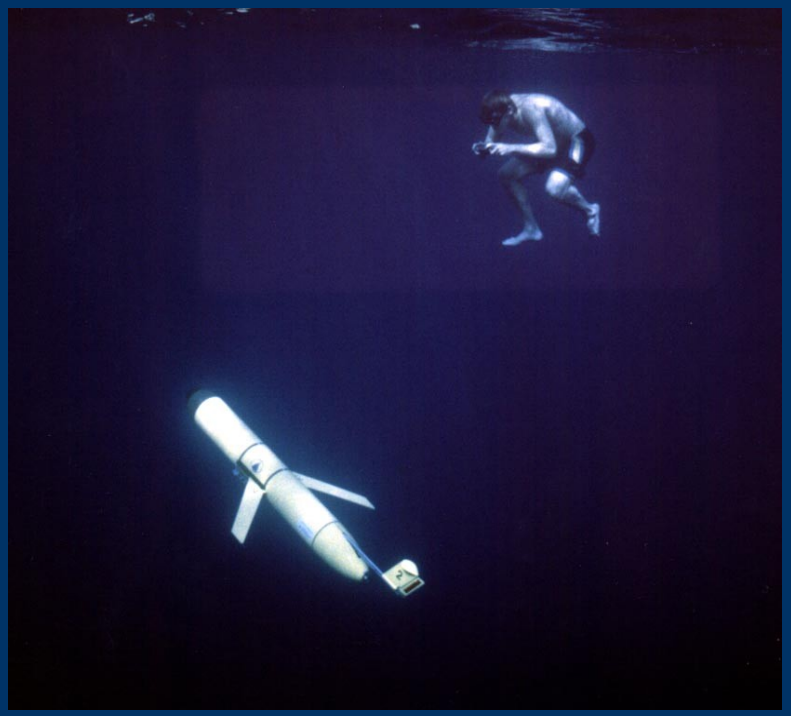


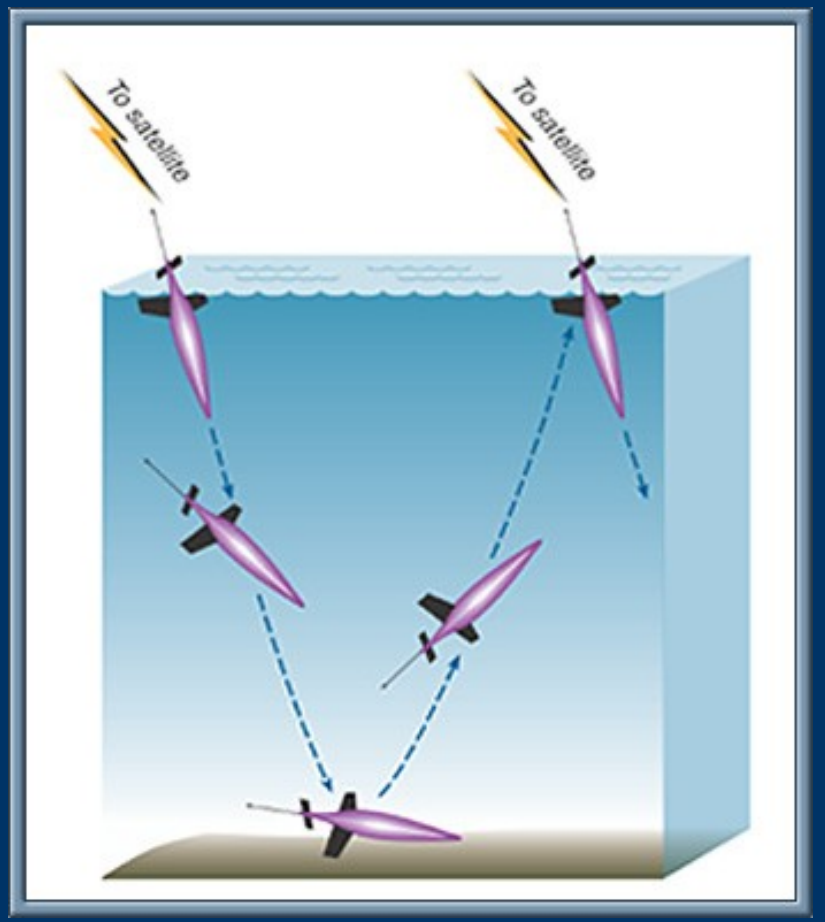




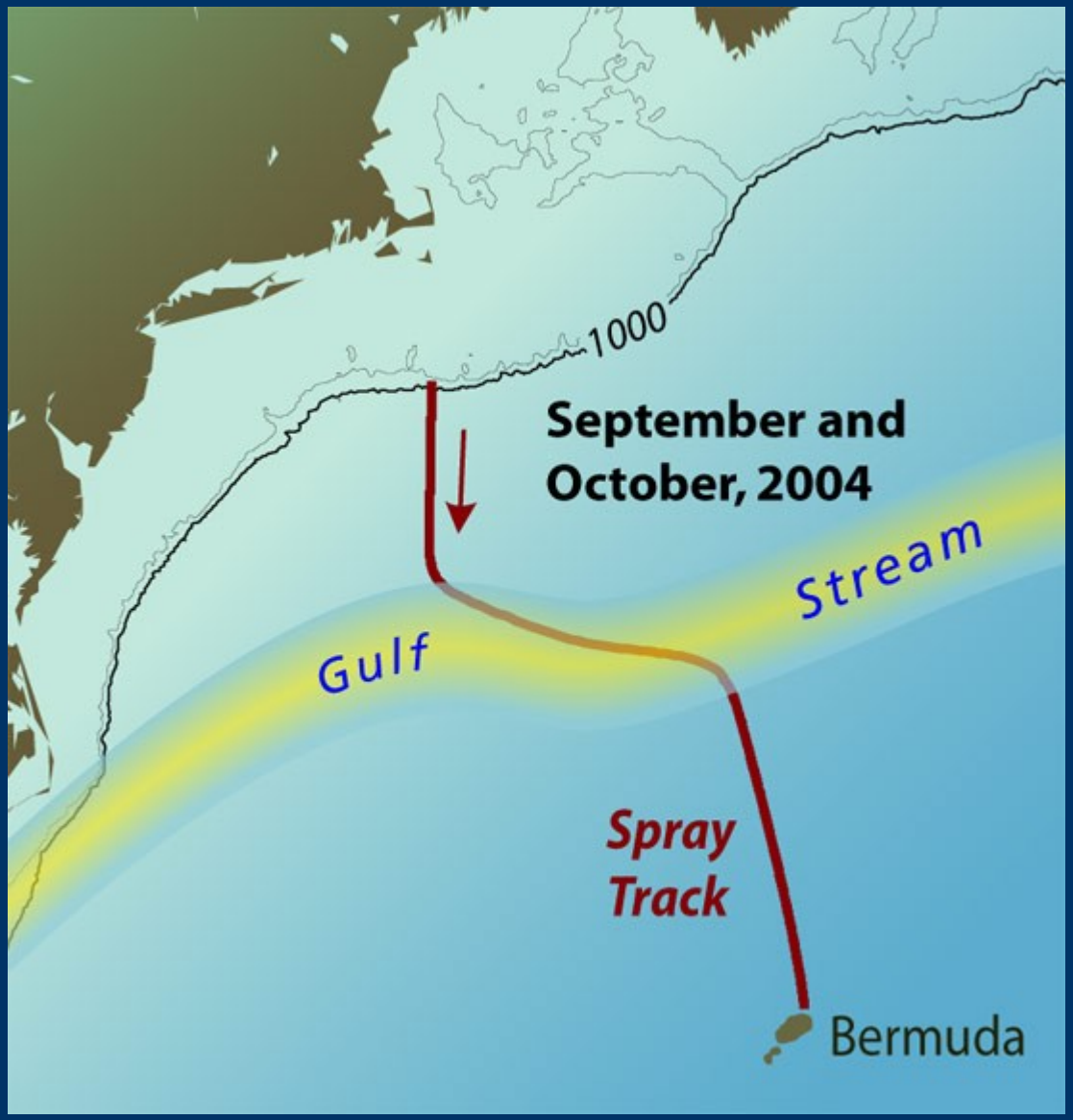
Gliders

- Use buoyancy to float up and down
- Fly forward using wings
- Low power
- Good for long range surveys



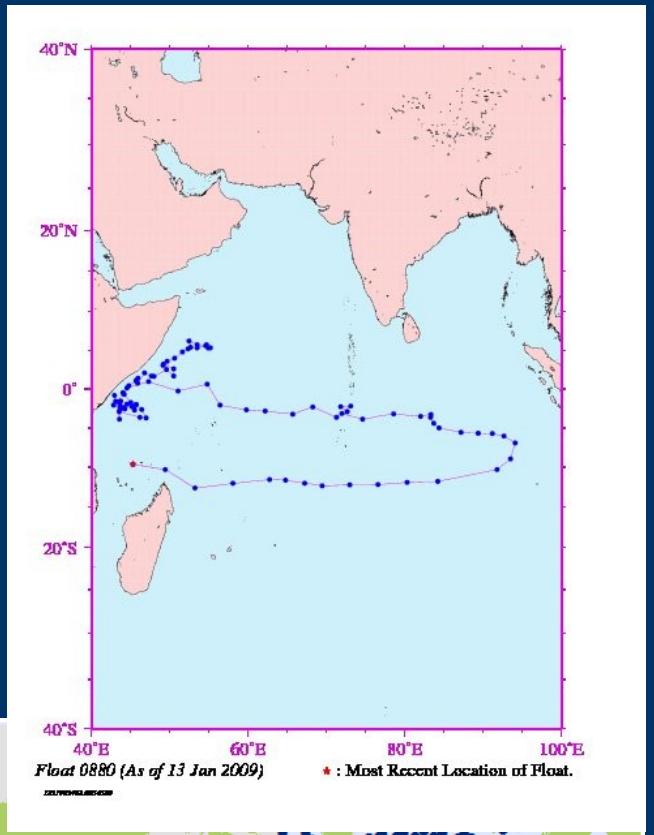


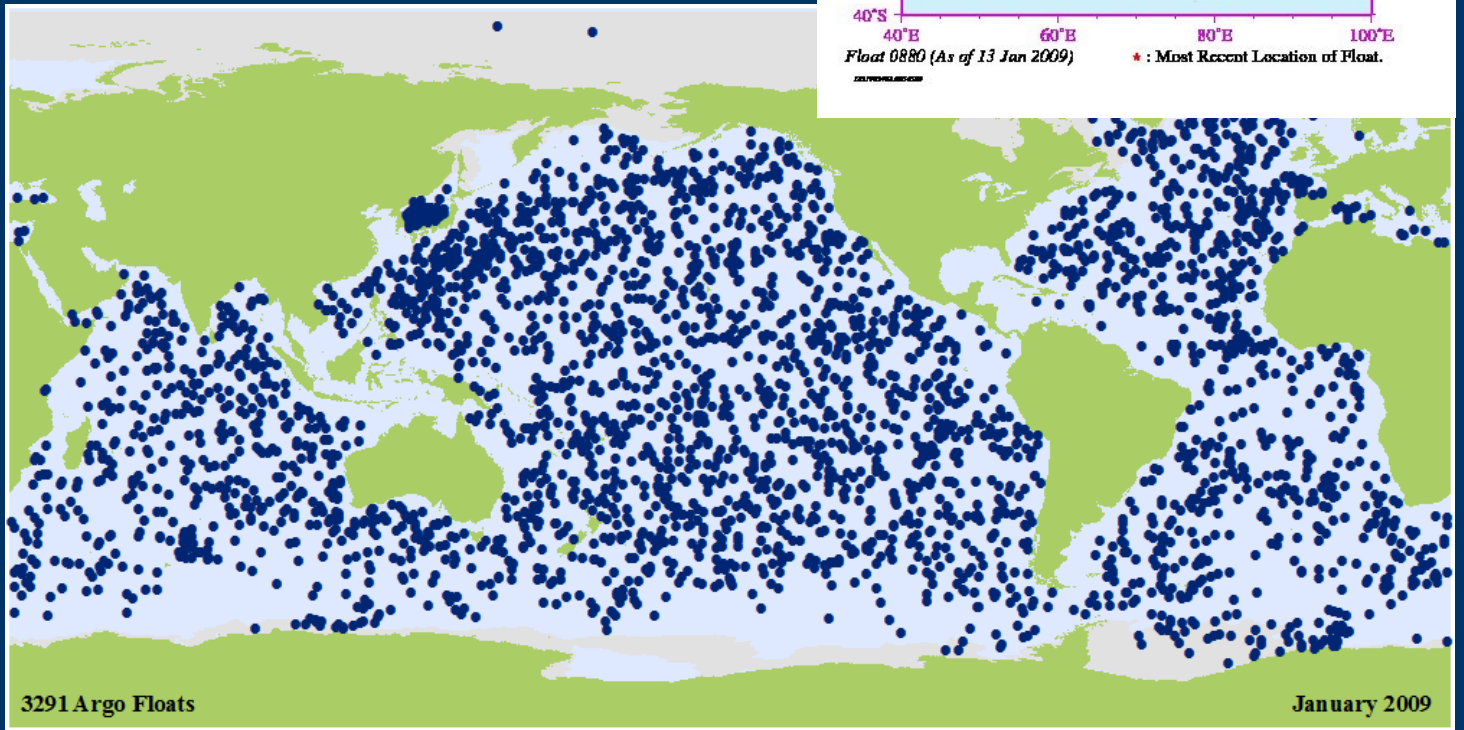
Long distance glider track



Floats

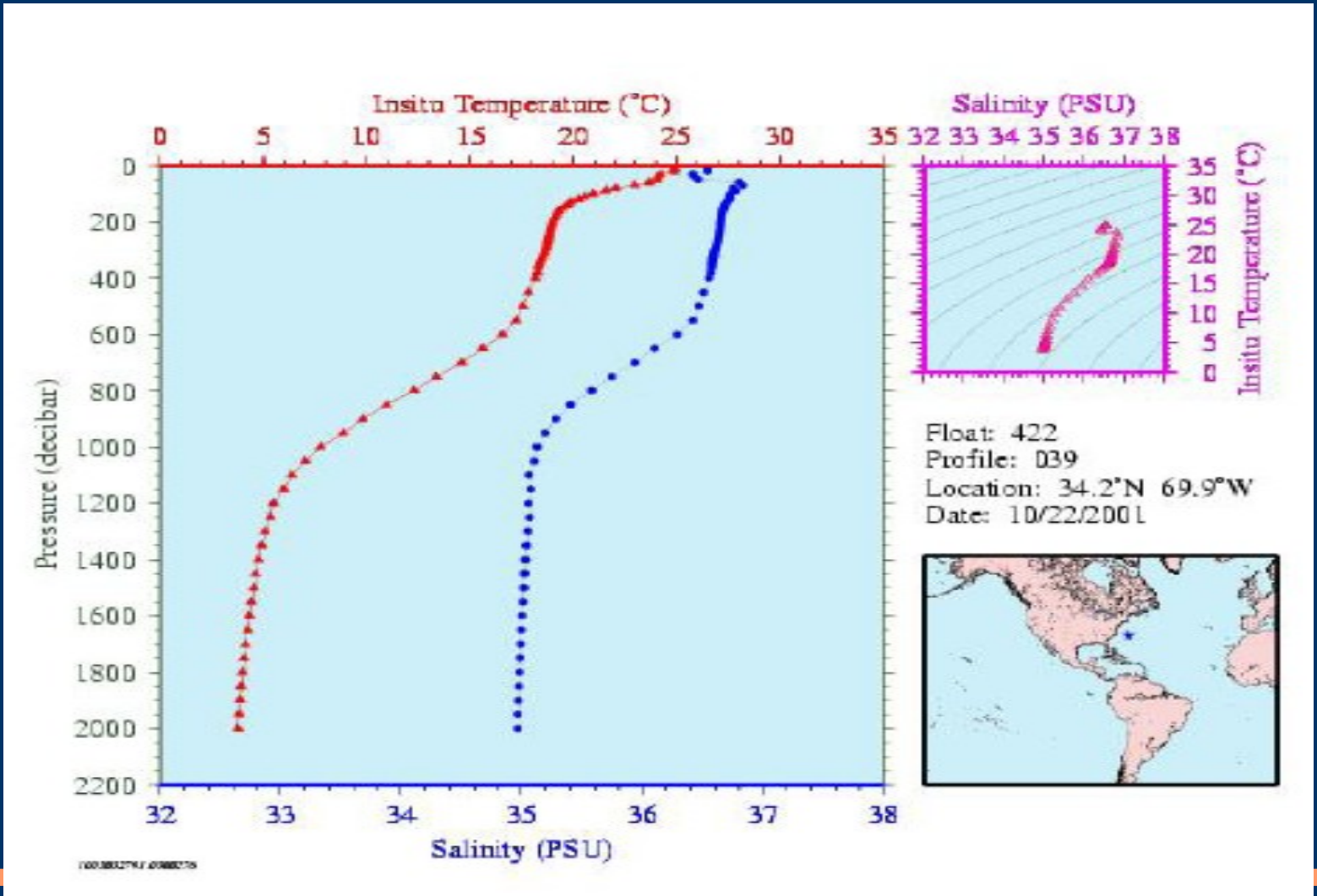
- Make vertical profiles with measurements
- Drift with the currents





Typical float profile

- Standard (Temperature, Salinity, Pressure)
- Now also measuring optical properties - phytoplankton



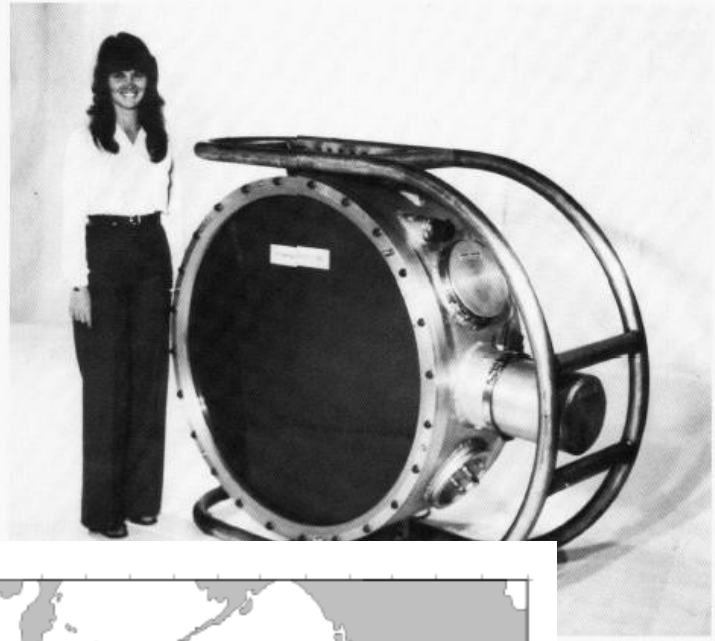
Figuring out where you are

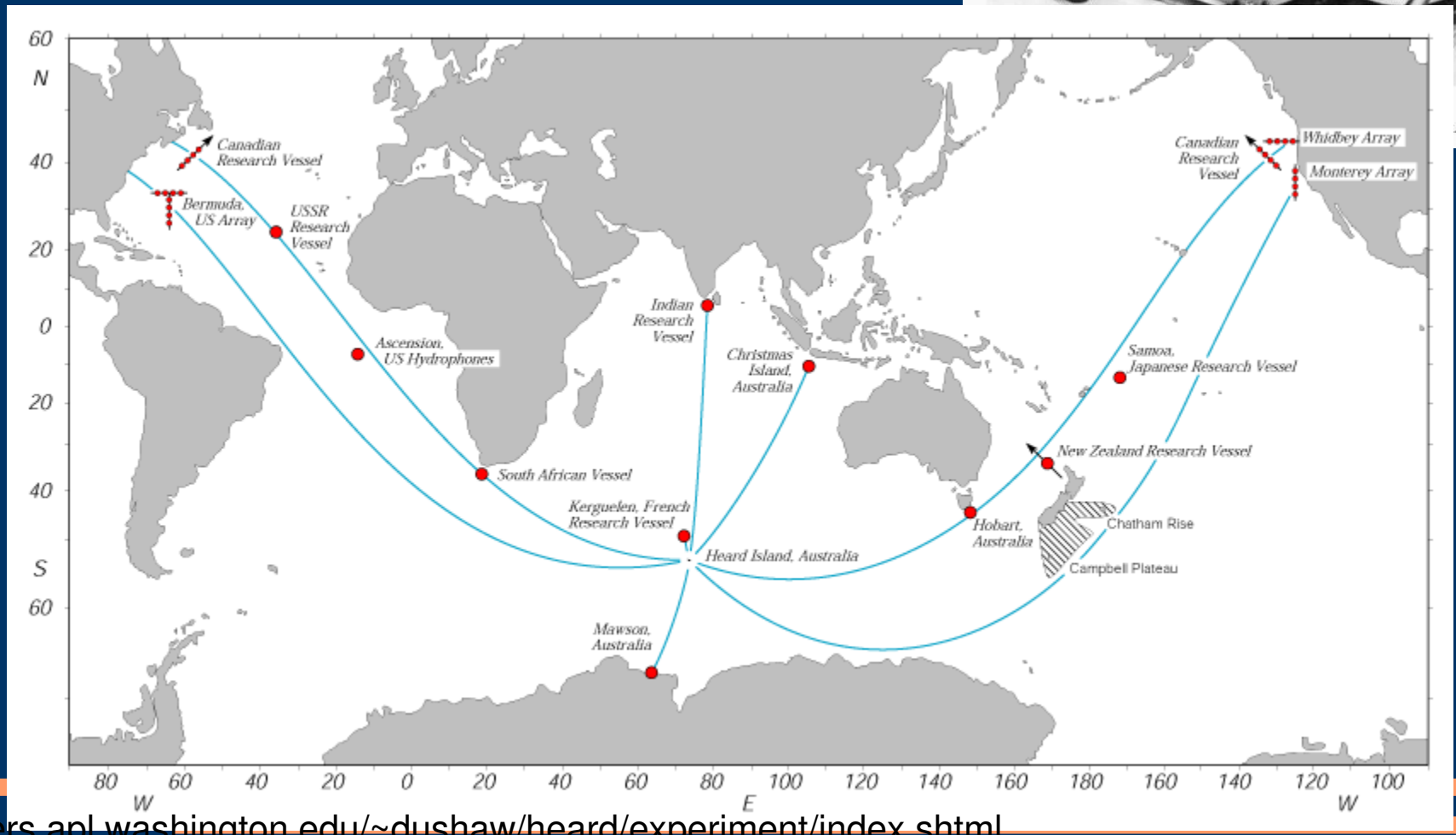
- Options:
  - GPS - Satellite based
  - Acoustic Triangulation
  - Dead Reckoning
  - Acoustic range and bearing

Frequency	Range	Example
< 250 Hz	10,000 Km	Seismics & Tomography
250 Hz	1000's Km	**FLOATS**
10 kHz	10 Km	Underwater positioning
20-50 kHz	2 Km	Acoustic Modem
300 kHz	300 m	ADCP
1-10 MHz	1 m or less	Medical Ultrasound

Heard Island Test

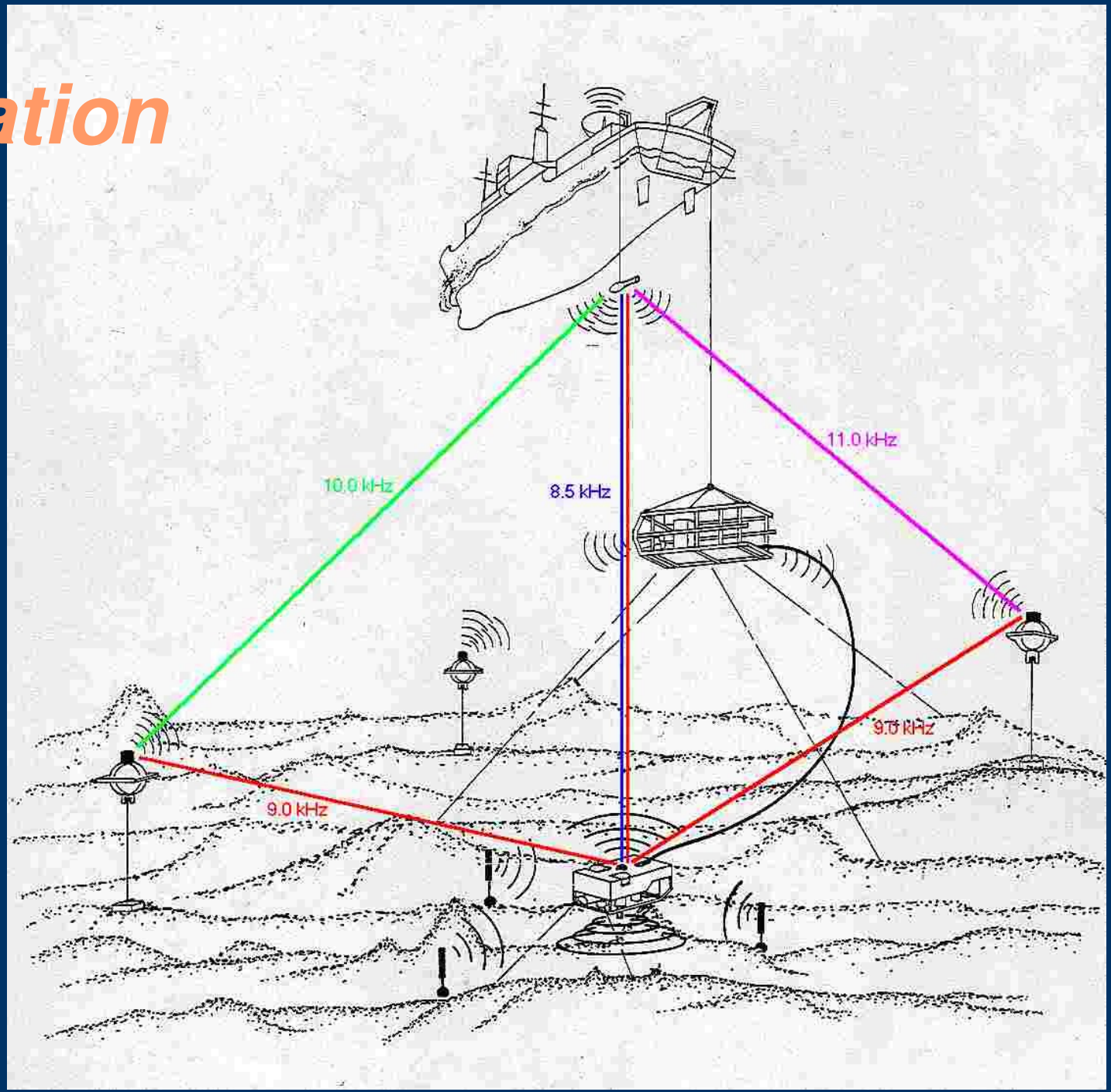
- 1991 – Walter Munk's ocean tomography experiment
- 206 db at 57 Hz





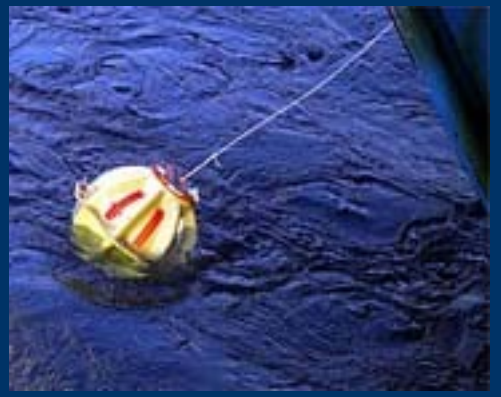
http://909ers.apl.washington.edu/~dushaw/heard/experiment/index.shtml

Triangulation

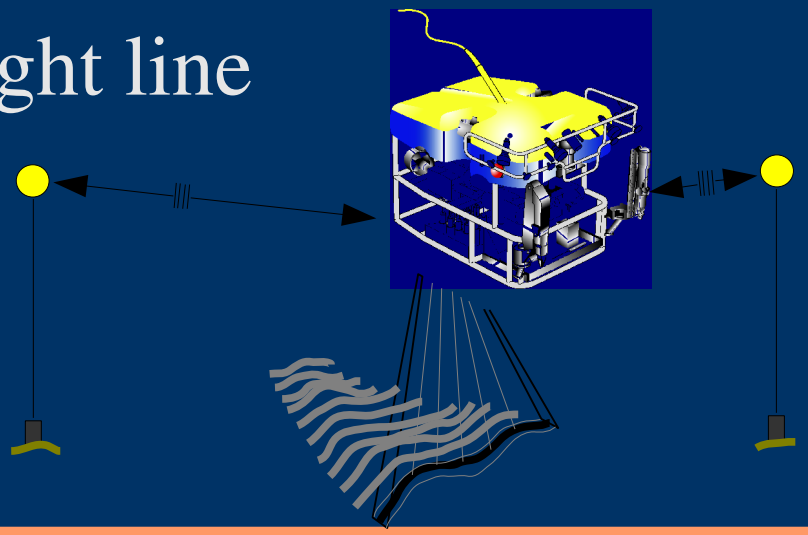


Acoustic range triangulation

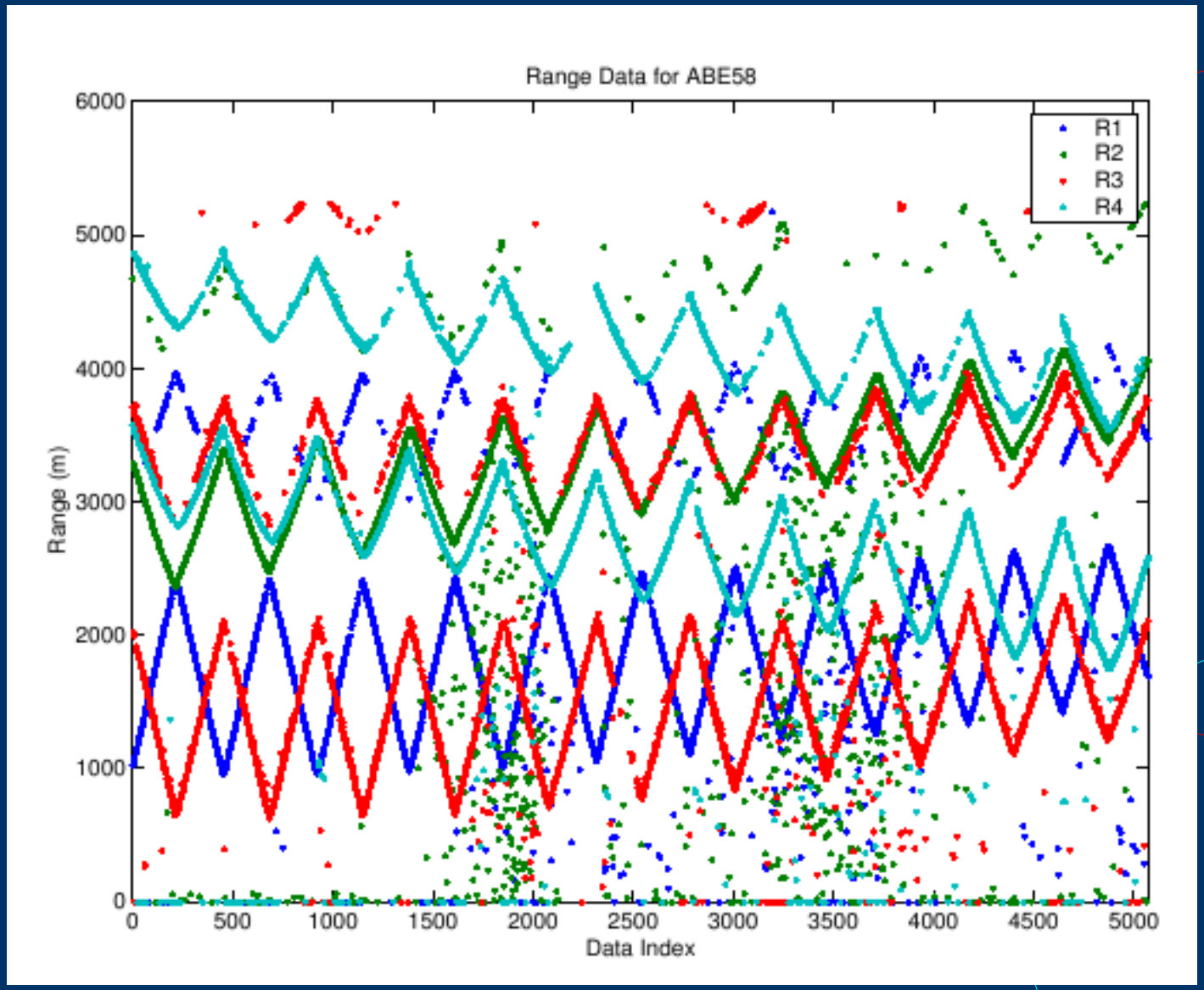
Pros: Can be very accurate
"Error" resets every time



Con: Lots of gear to deploy
Have to survey the beacons
Beacons can move in the current
Sound doesn't go in a straight line



Real ranges can be tricky



Dead reckoning

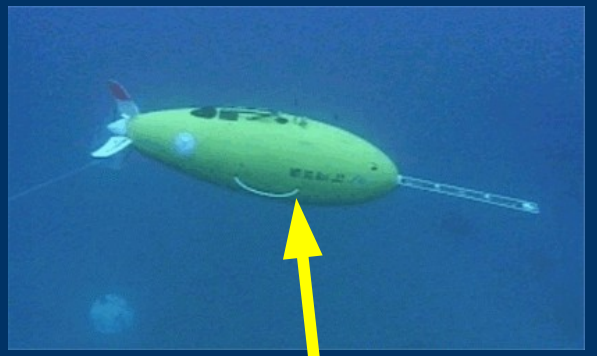
- What do you need to measure?
  - Velocity
  - Heading

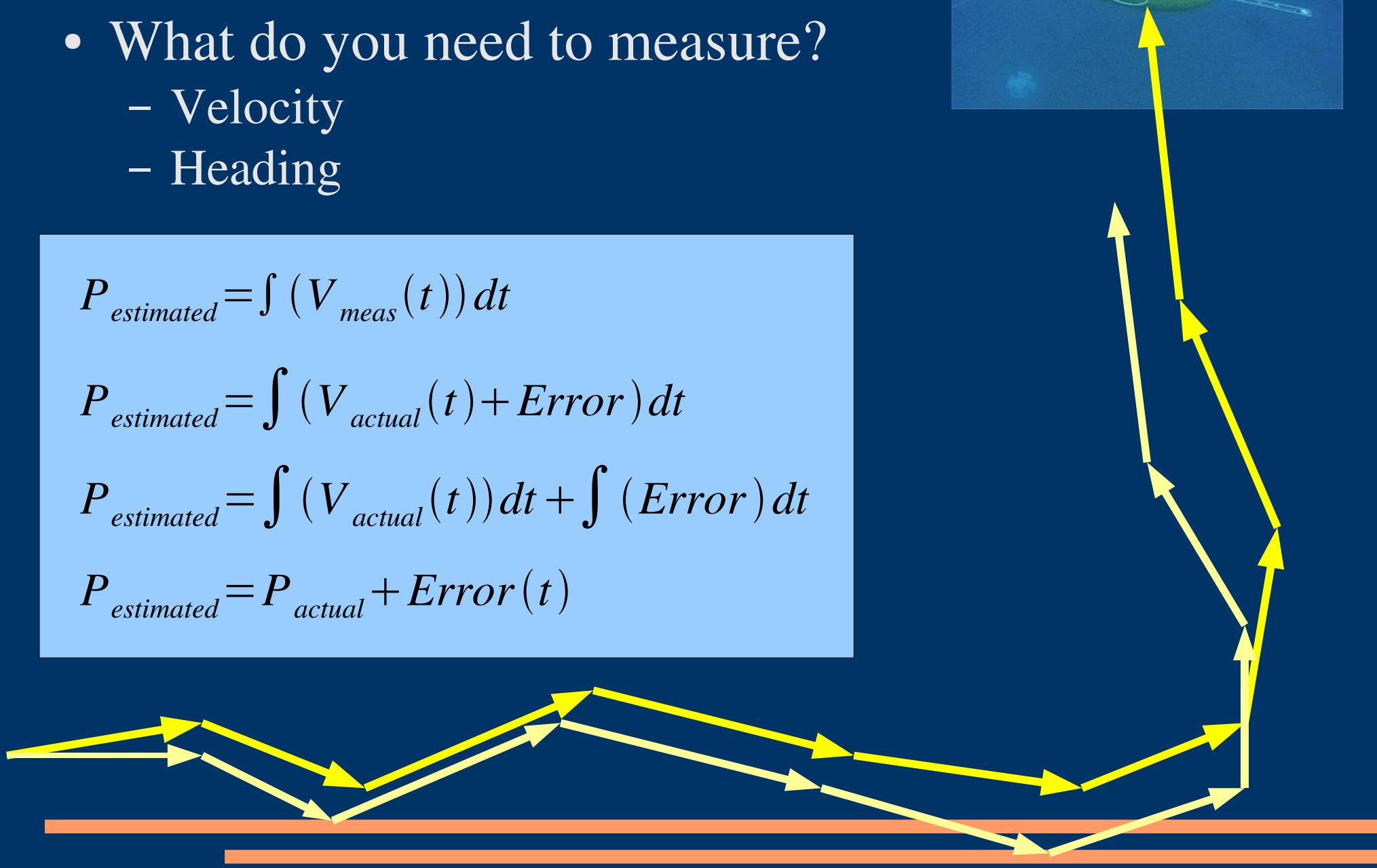
$$P_{estimated} = \int (V_{meas}(t))\,dt$$

$$P_{estimated} = \int (V_{actual}(t) + Error)\,dt$$

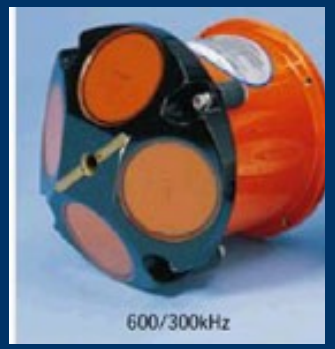
$$P_{estimated} = \int (V_{actual}(t))\,dt + \int (Error)\,dt$$

$$P_{estimated} = P_{actual} + Error(t)$$

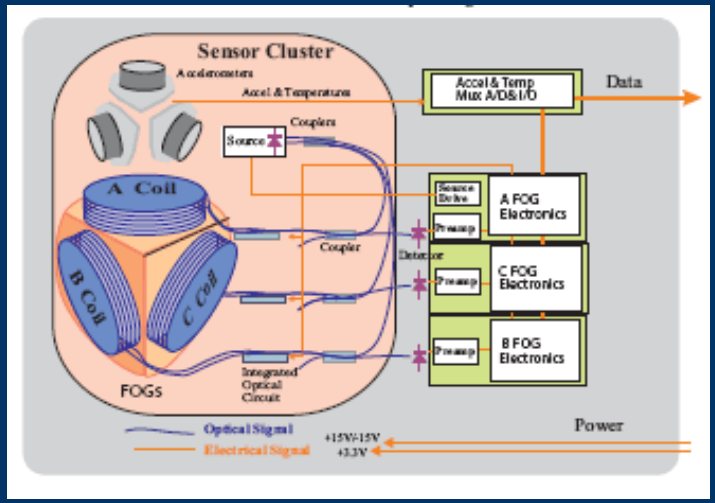




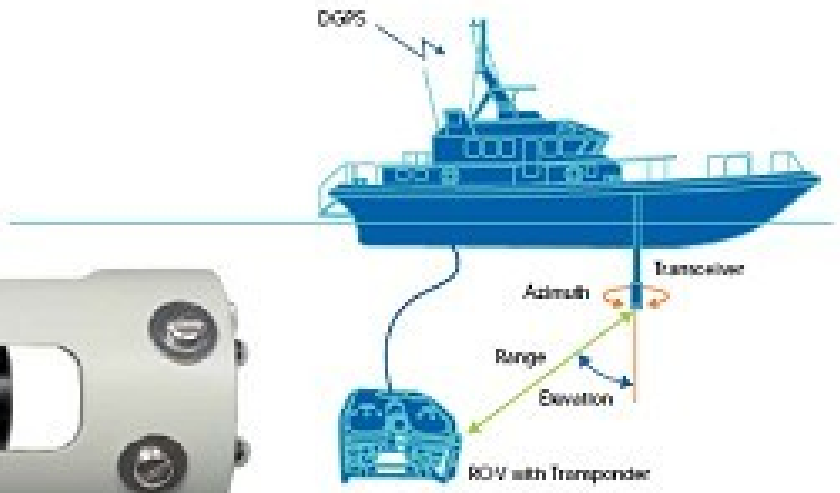
Dead reckoning



- Pros:
  - Easy
  - Does not need external gear to be deployed
- Cons:
  - Errors grow with time and distance
  - Not absolute, it is only a relative measurement
  - Need a really good heading sensor
    - Compasses are bad
    - Fiber optic gyro's are good



Acoustic range and bearing



Acoustic array?

- Measure angles using time delays

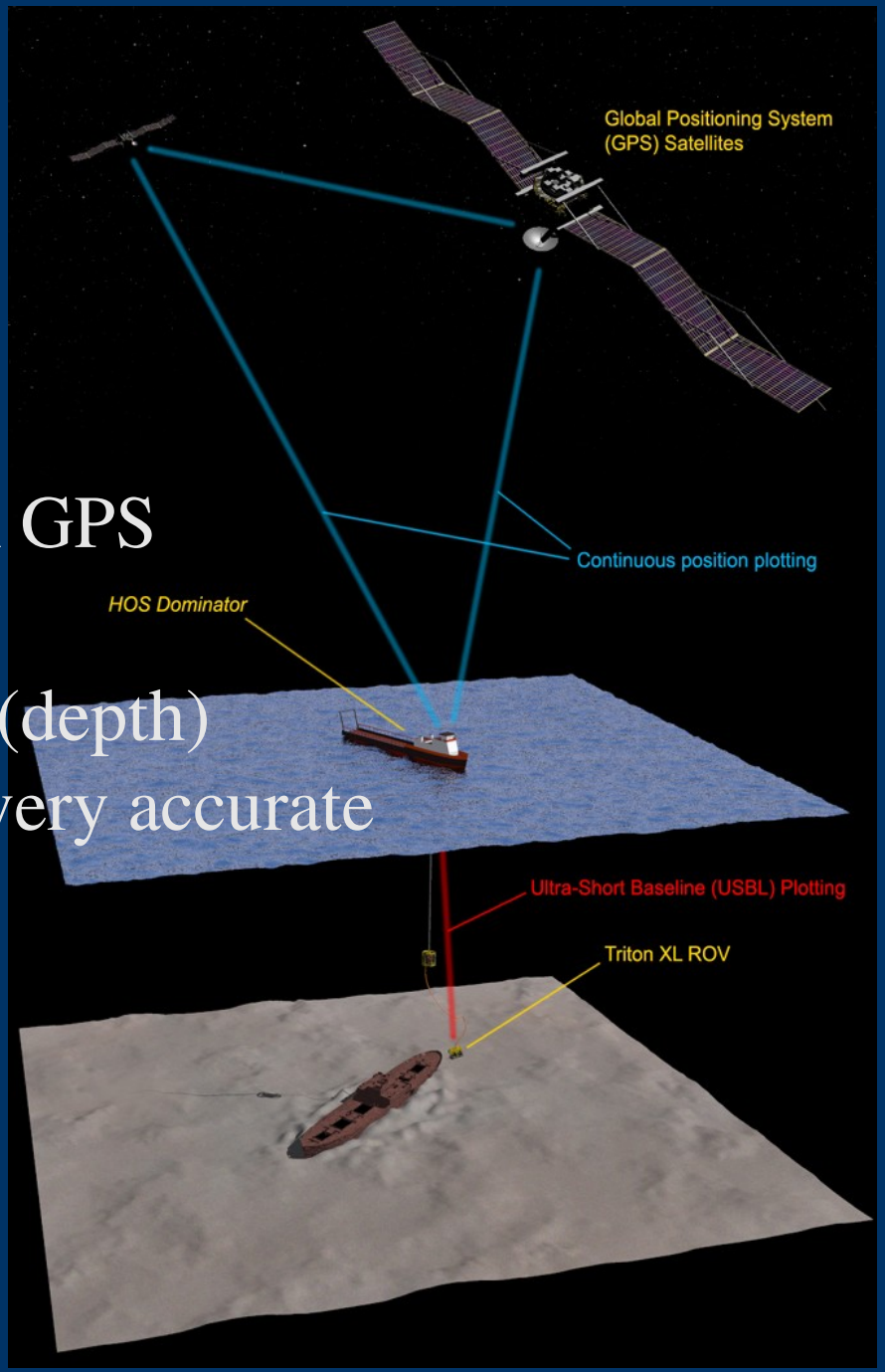
Hydrophones

Sound waves

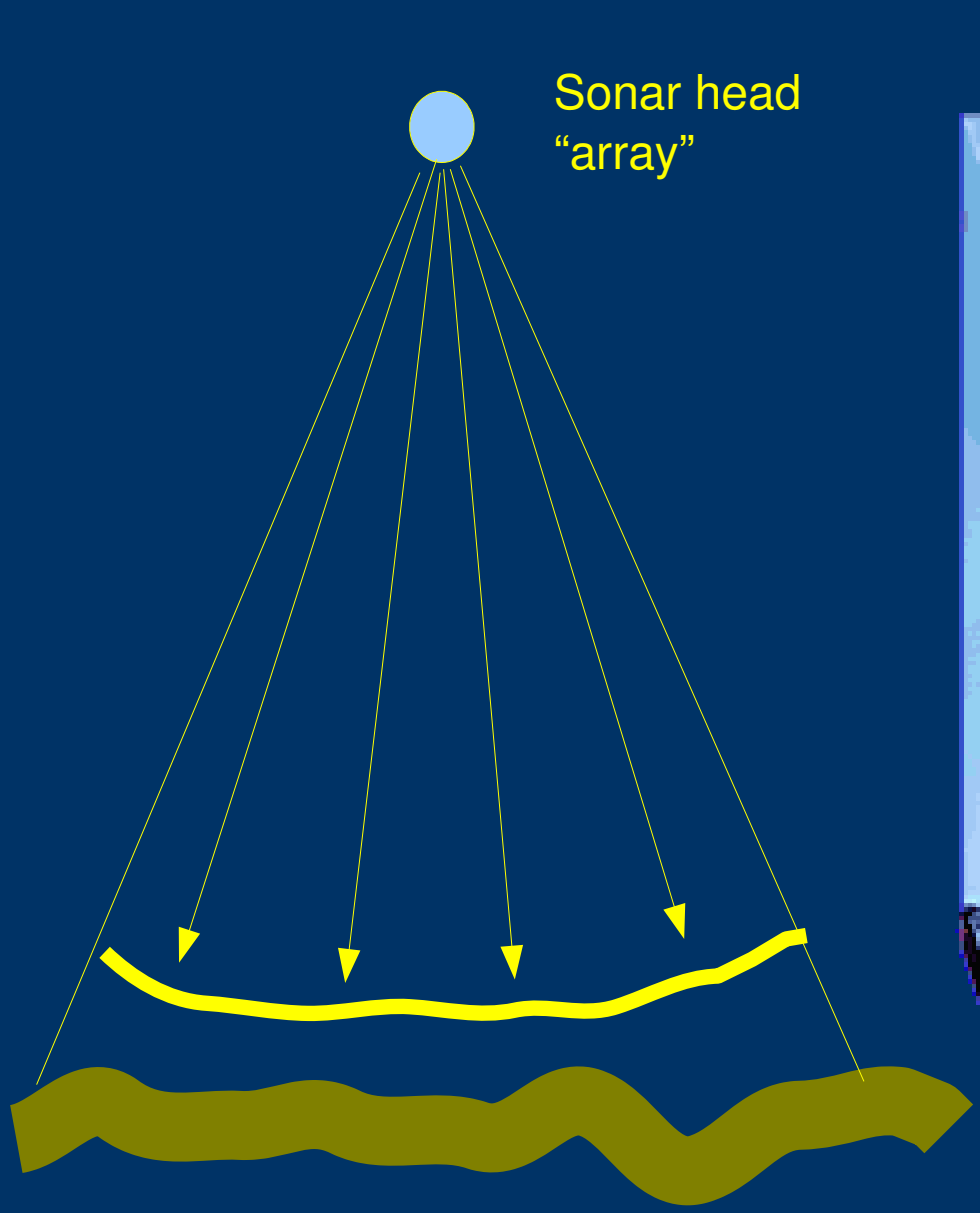
Time delay

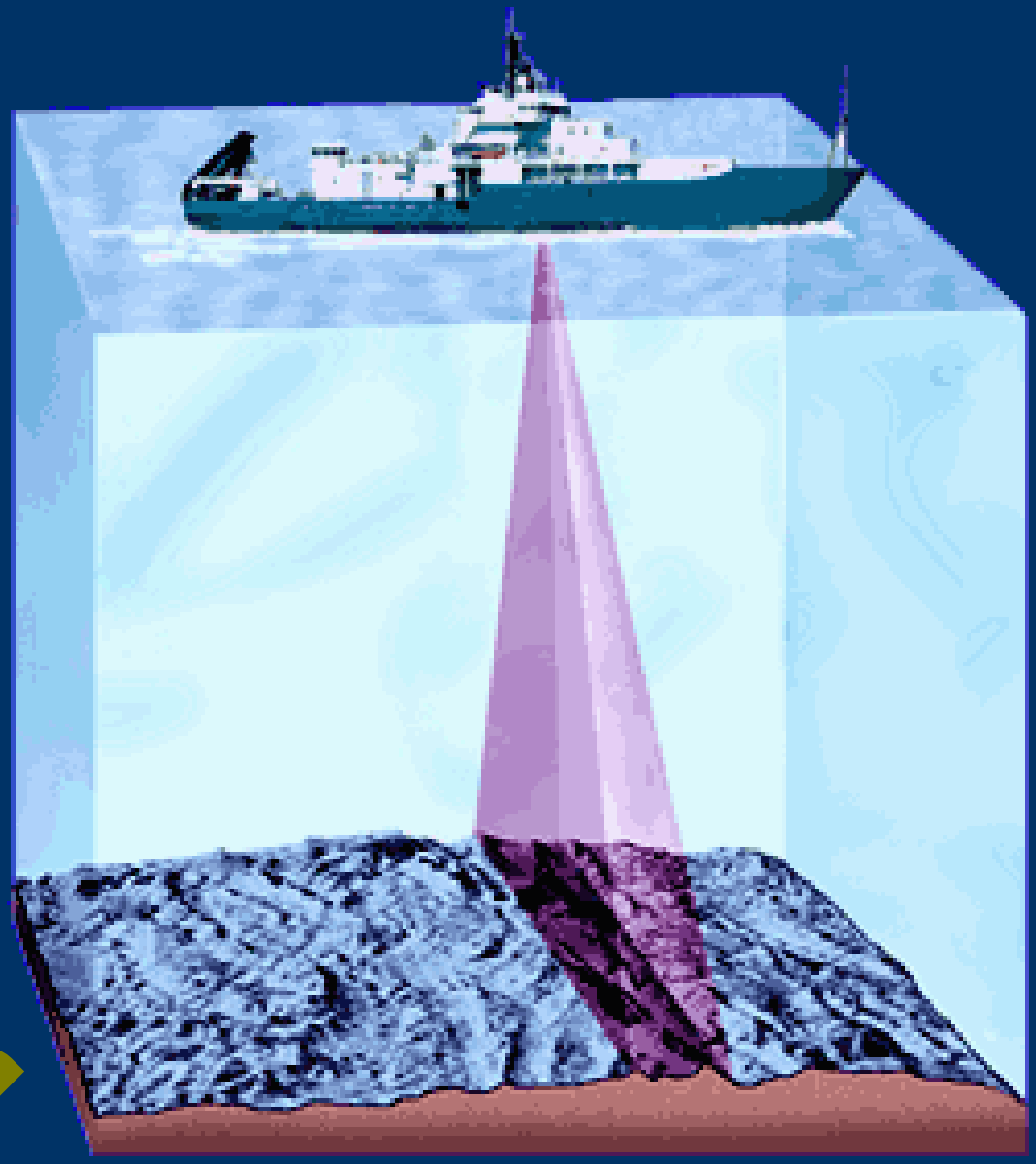
Acoustic range and bearing

- Pros:
  - Easy to do from a ship
  - Can be absolute when used with GPS
- Cons:
  - Accuracy is a function of range (depth)
  - Needs a lot of calibration to be very accurate



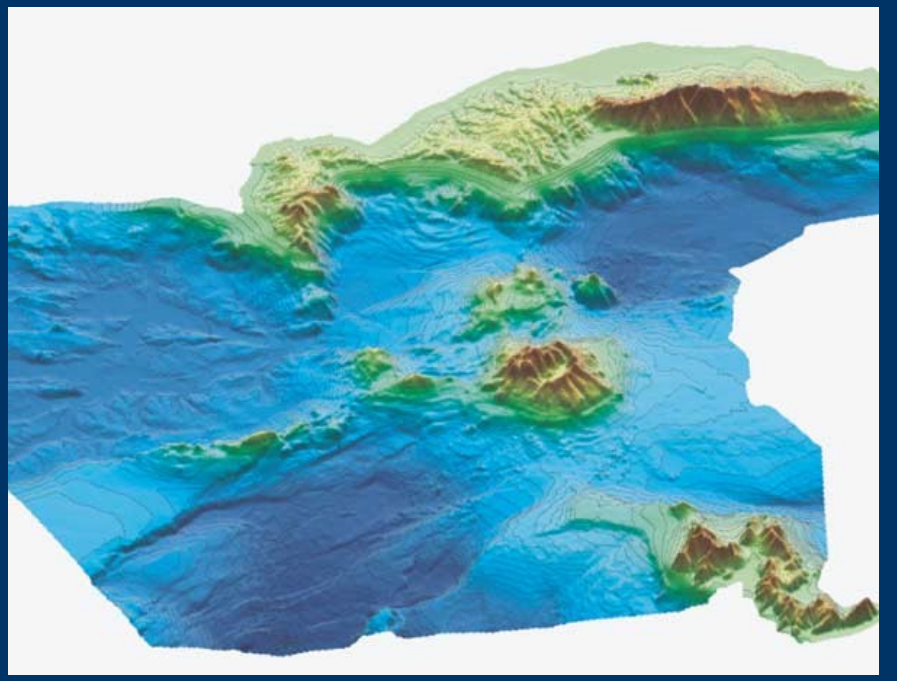
Sensors – mapping sensors





Ship surveys

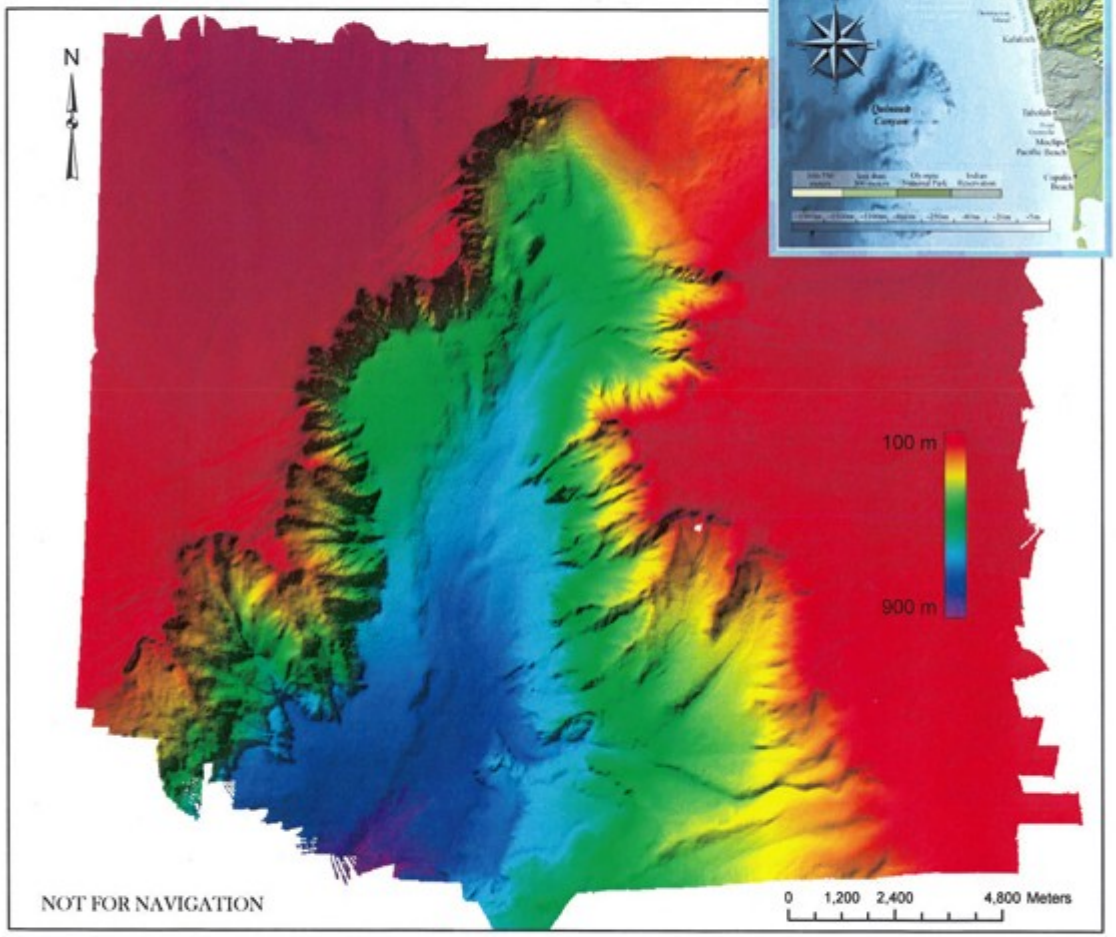
- Full ocean depths
- Accuracy depends on depth



Olympic Coast National Marine Sanctuary

Juan de Fuca Canyon

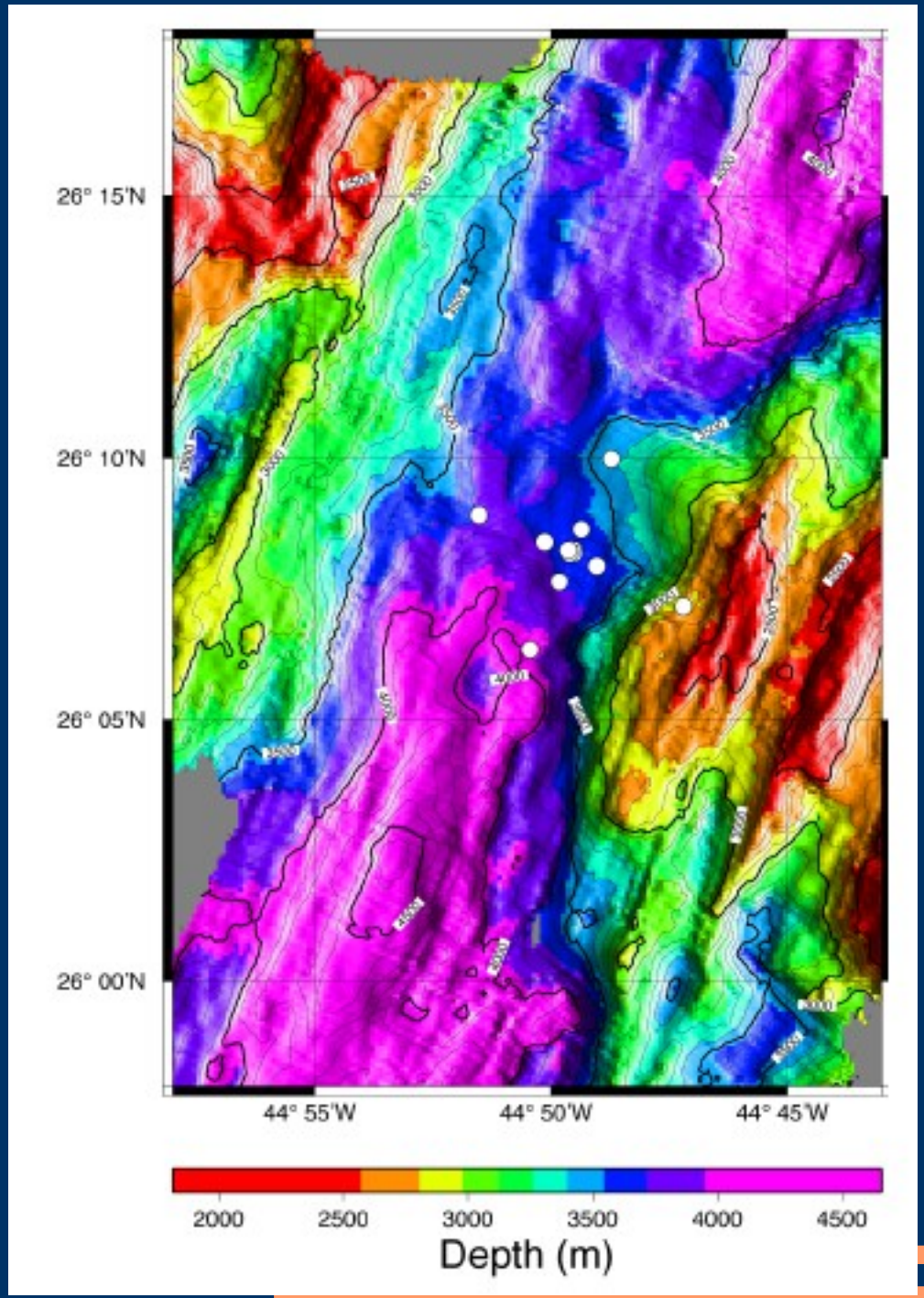
FIRST Exploration Survey by the NOAA Ship Okeanos Explorer
September 2008

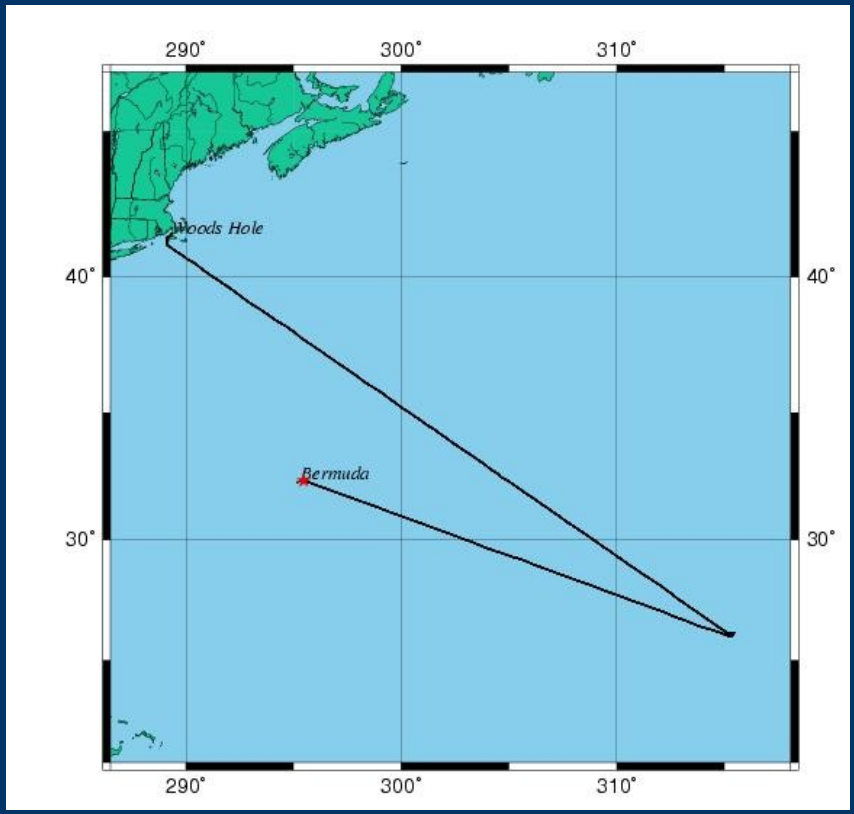


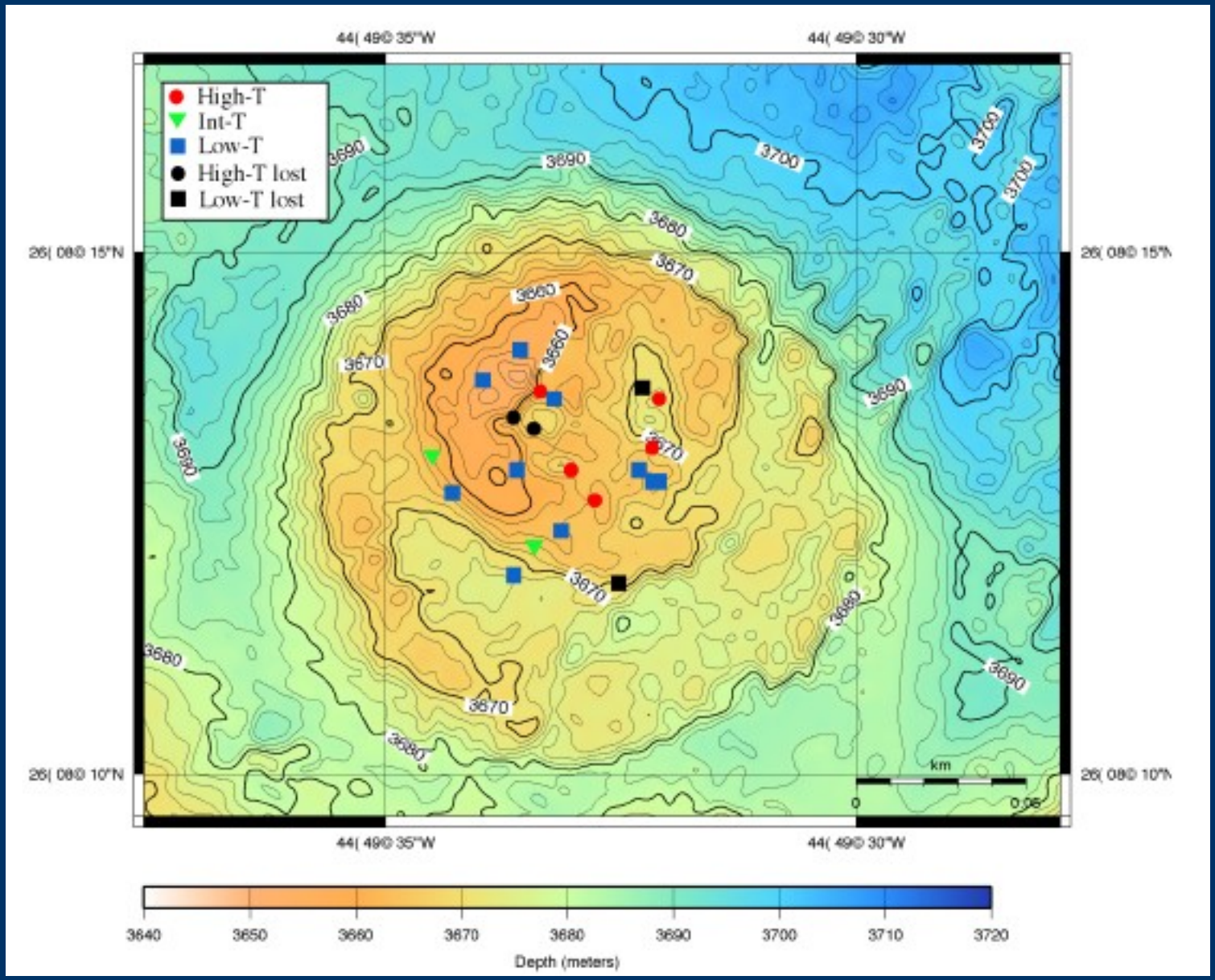
OCEAN EXPLORATION & RESEARCH
THE NOAA SHIP OKEANOS EXPLORER

CDR Joseph Pica, Commanding Officer

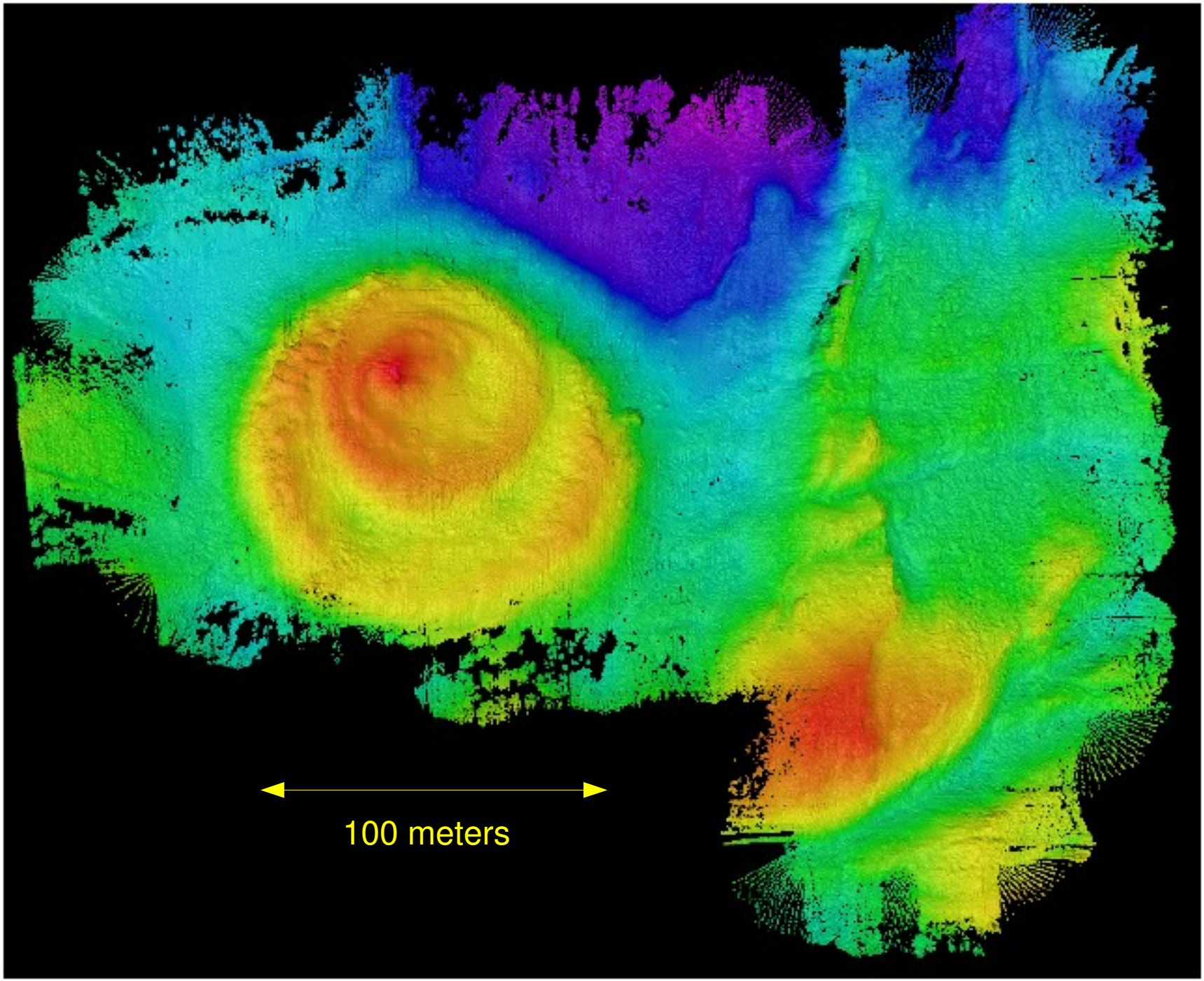
NOAA


26° 15'N
26° 10'N
26° 05'N
26° 00'N
44° 55'W
44° 50'W
44° 45'W
2000
2500
3000
3500
4000
4500
Depth (m)

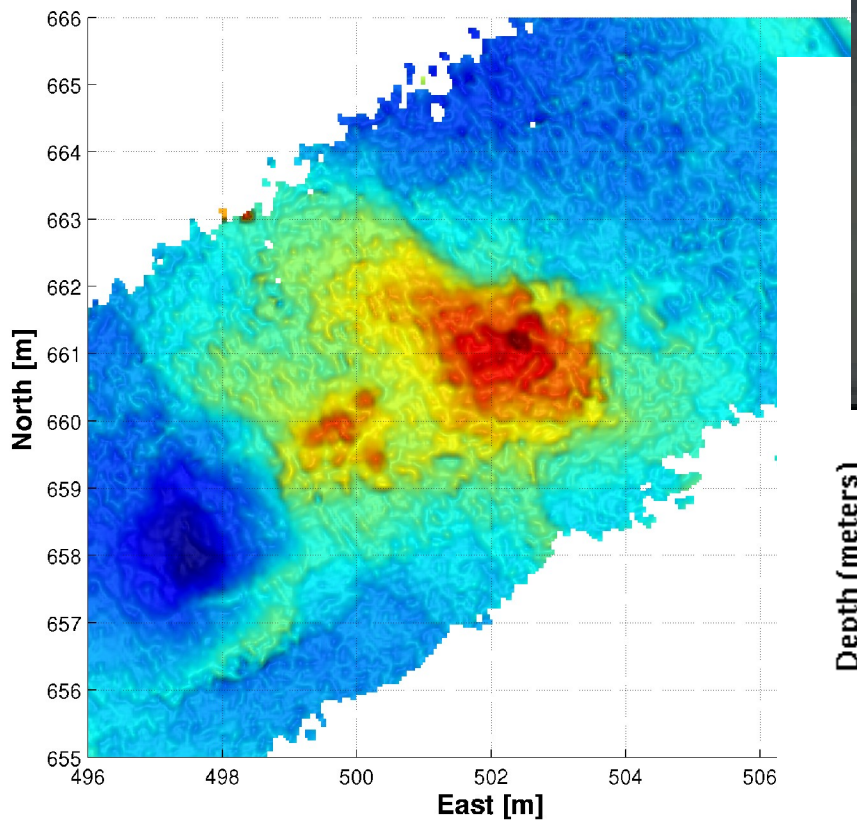

290°
300°
310°
40°
30°
Woods Hole
Bermuda

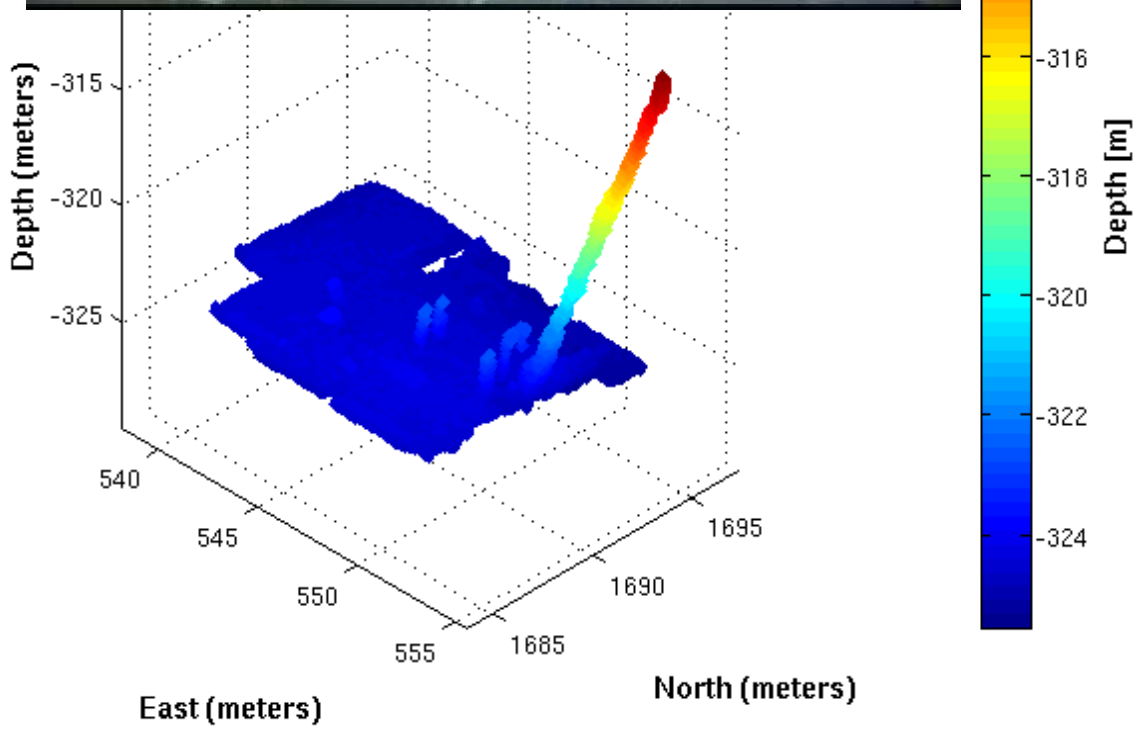

44(49© 35"W
44(49© 30"W
26(08© 15"N
26(08© 10"N
High-T
Int-T
Low-T
High-T lost
Low-T lost
3690
3700
3680
3670
3660
km
0
0.05
3640
3650
3660
3670
3680
3690
3700
3710
3720
Depth (meters)


• THE KECK FOUNDATION
• THE NATIONAL SCIENCE FOUNDATION
ROSS SWISS
DAIRIES
DALLAS TX.


100 meters

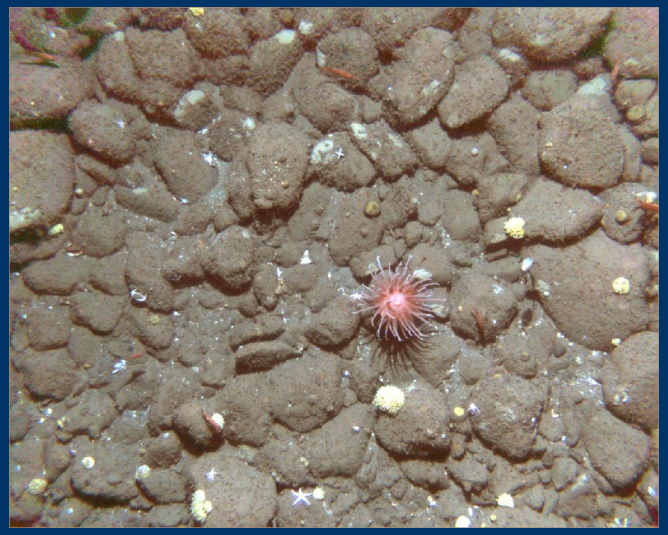
Multibeam con't

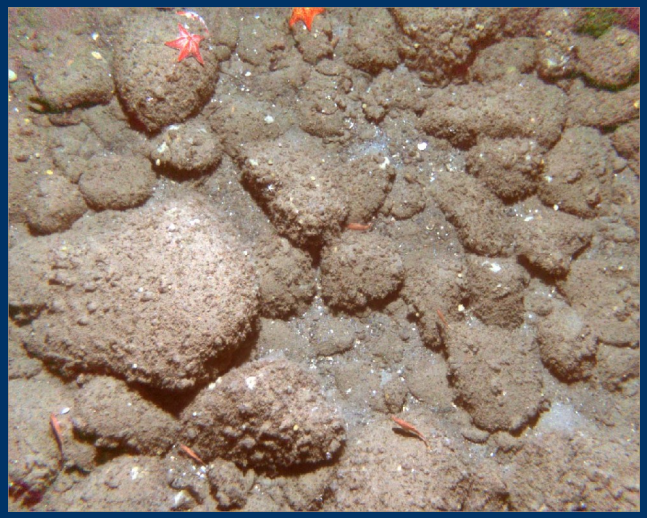




Visual imaging

- Useful to combine underwater images
- Getting a single picture bigger than a few square meters is tough
- Modern vehicles, ROV's AUV's can perform structured surveys

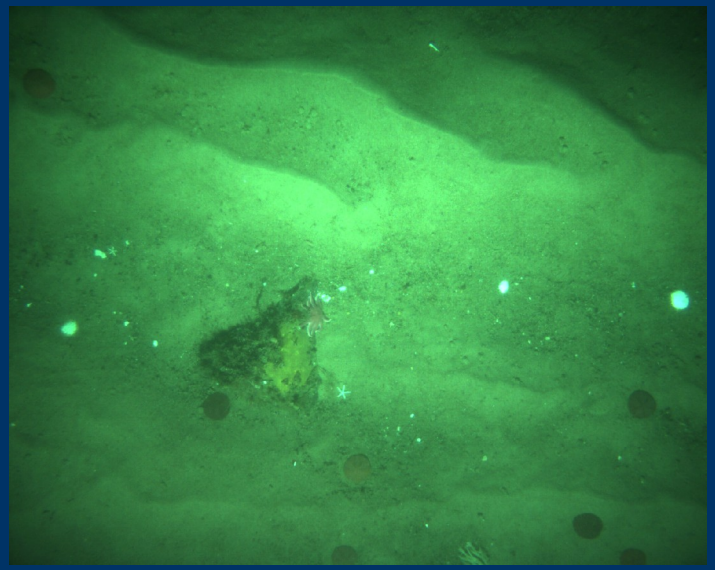


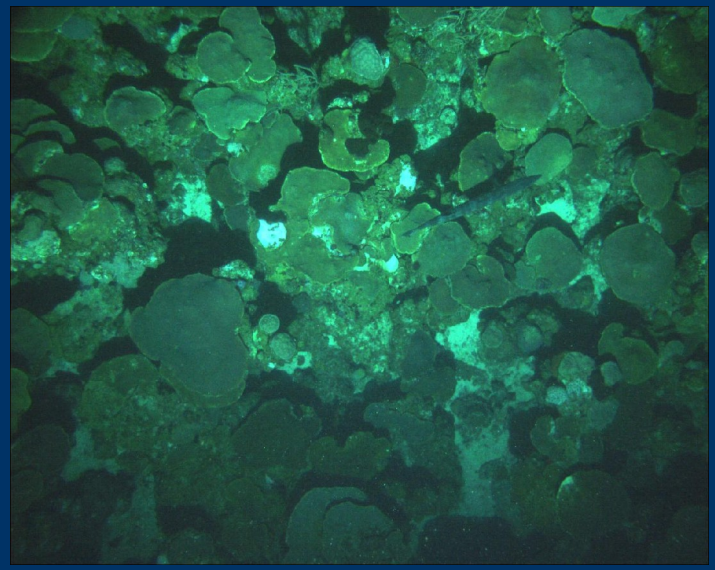


Photomosaicking

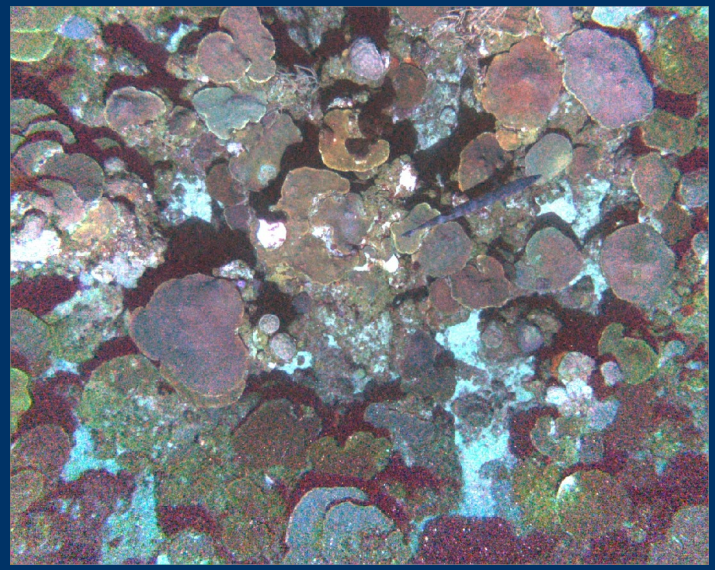
Color imaging, it's not that easy

Before



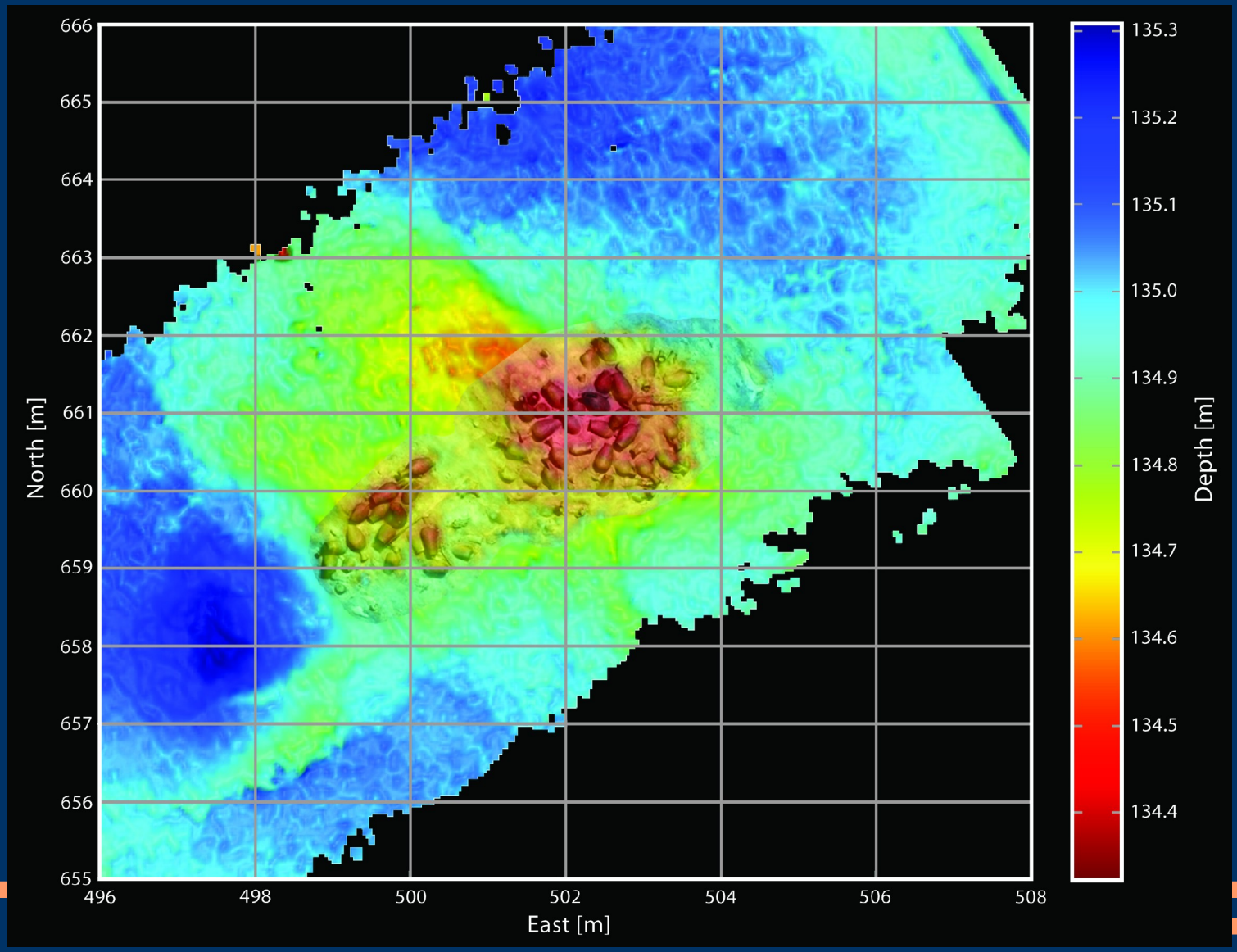


After



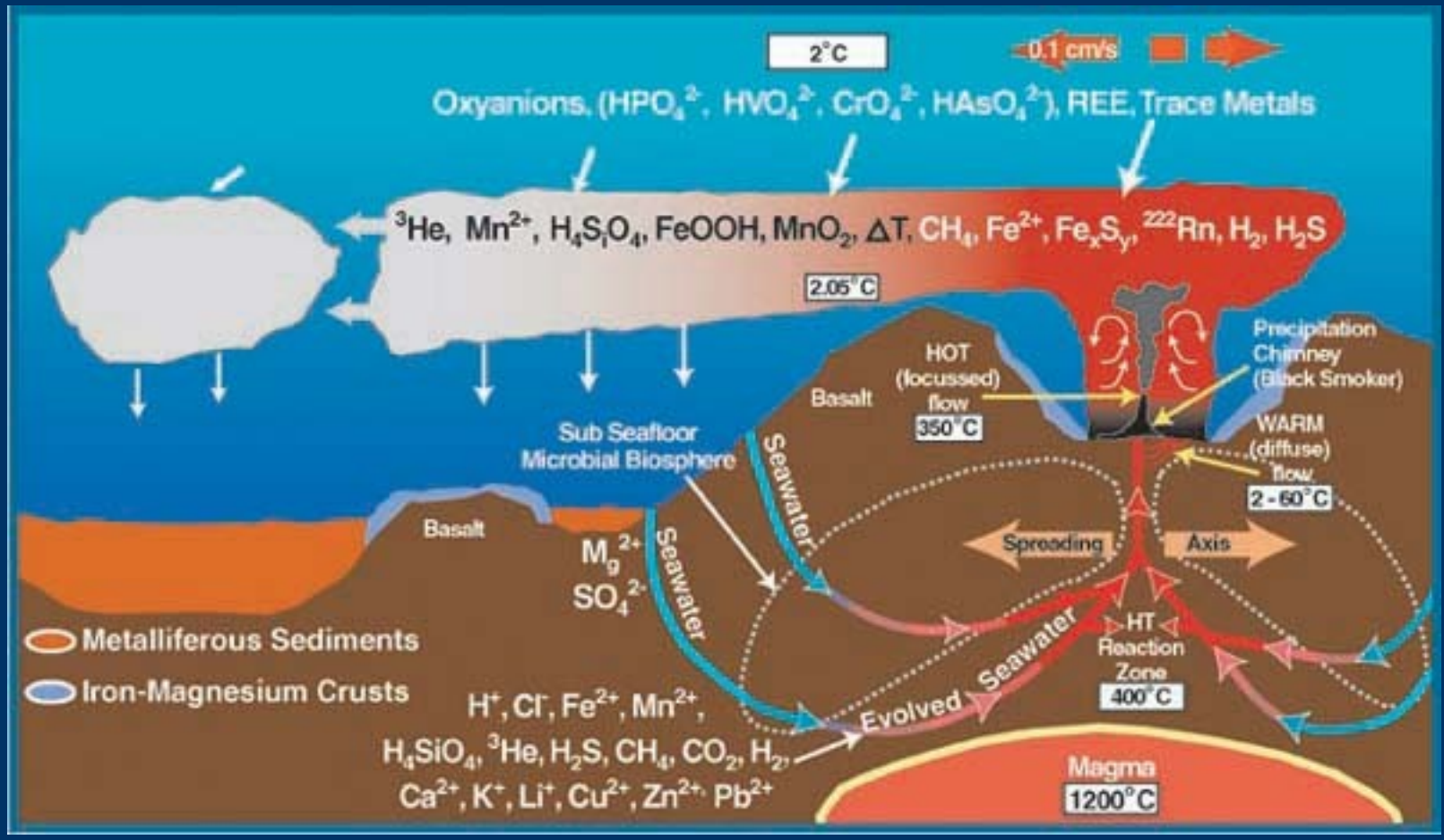
Merged bathymetry and mosaics

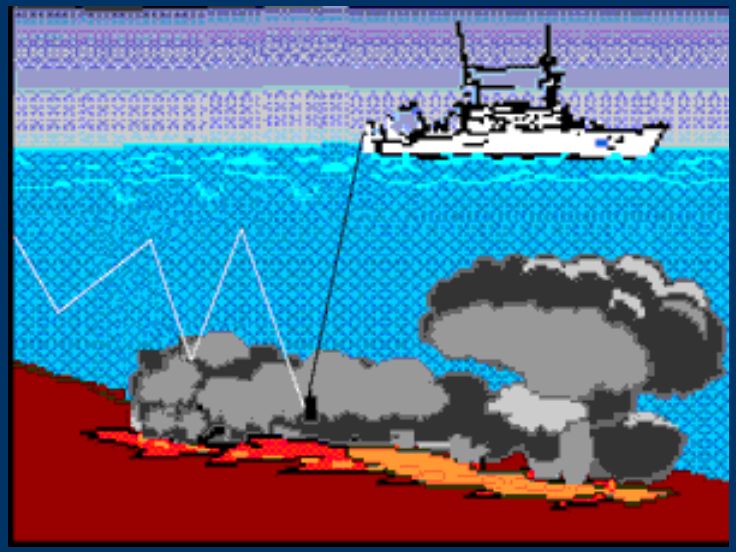
- Helps quantify scale in mosaics
- Understanding of scene relief

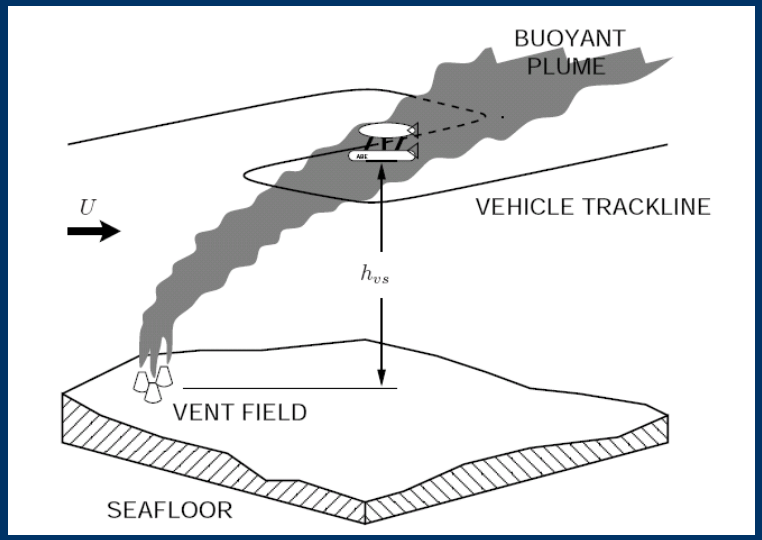


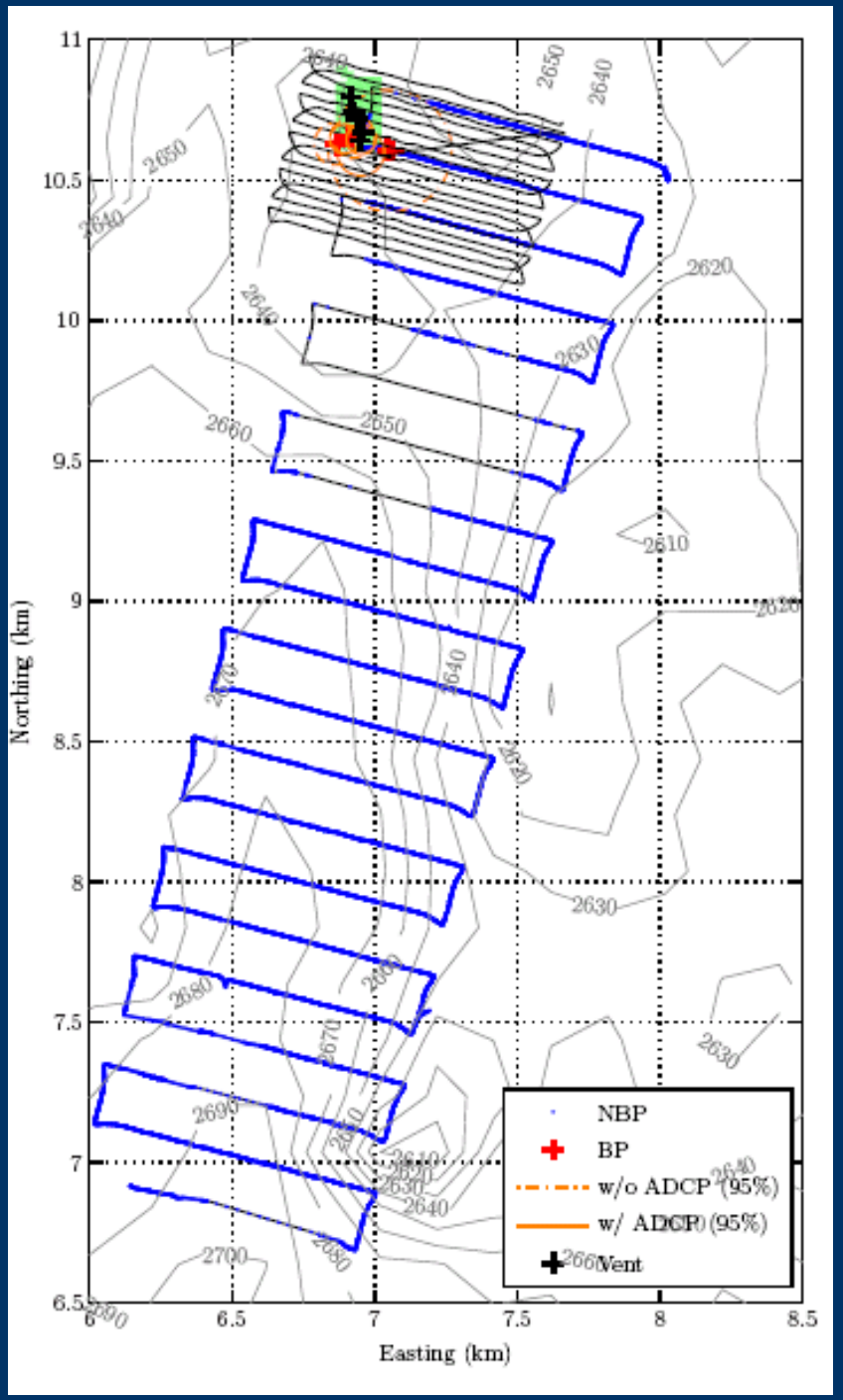
Hydrothermal plume mapping

- Vehicles can carry chemical sensors
- Help find plumes from





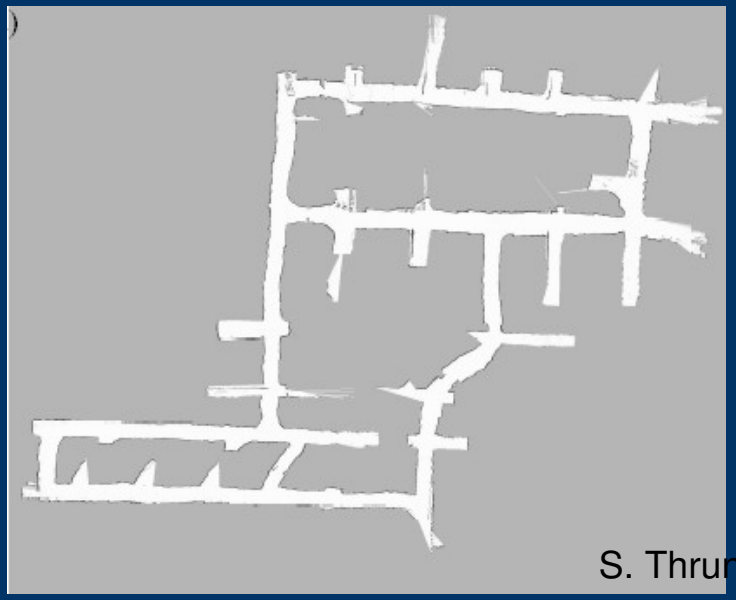

BUOYANT
PLUME
VEHICLE TRACKLINE
U
h_{vs}
VENT FIELD
SEAFLOOR


Northing (km)
Easting (km)
NBP
BP
w/o ADCP (95%)
w/ ADCP (95%)
Vent

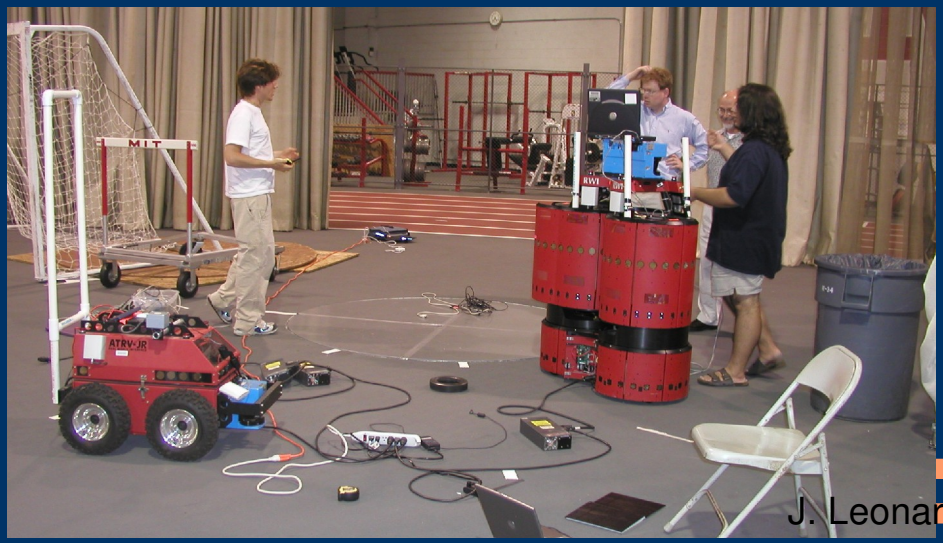
Related to robotics research

Simultaneous Mapping and Localization (SLAM)

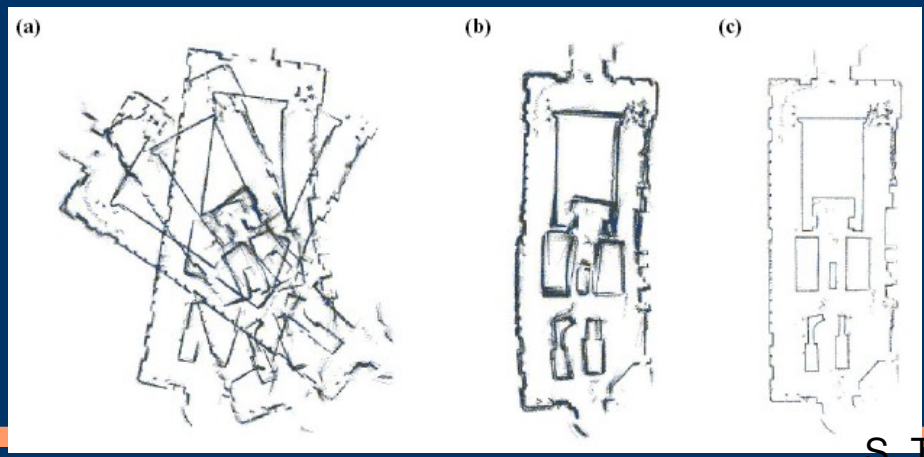
S. Thrun



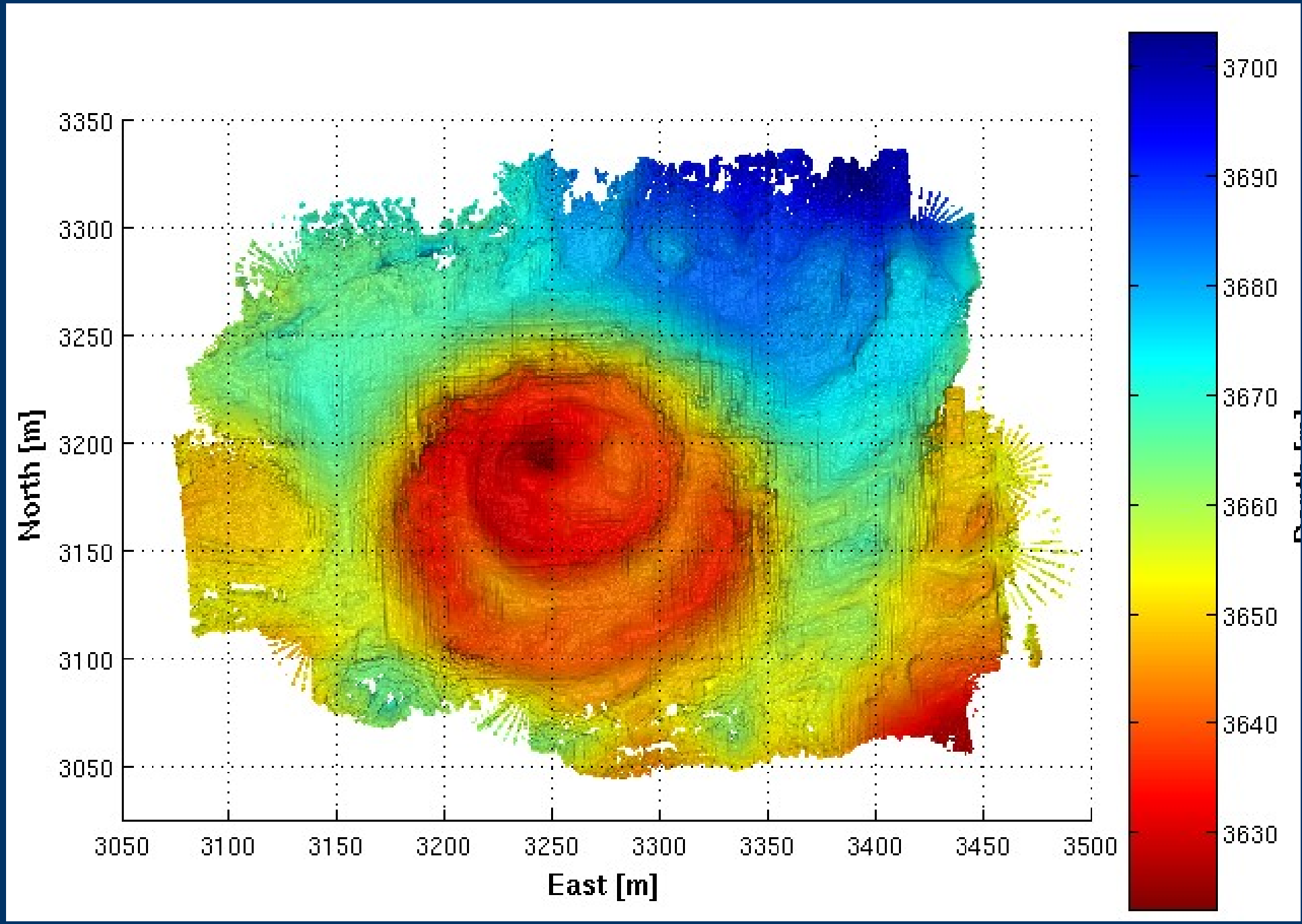
S. Thrun



J. Leonard



S. Thrun


North [m]
3350
3300
3250
3200
3150
3100
3050
East [m]
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
3700
3690
3680
3670
3660
3650
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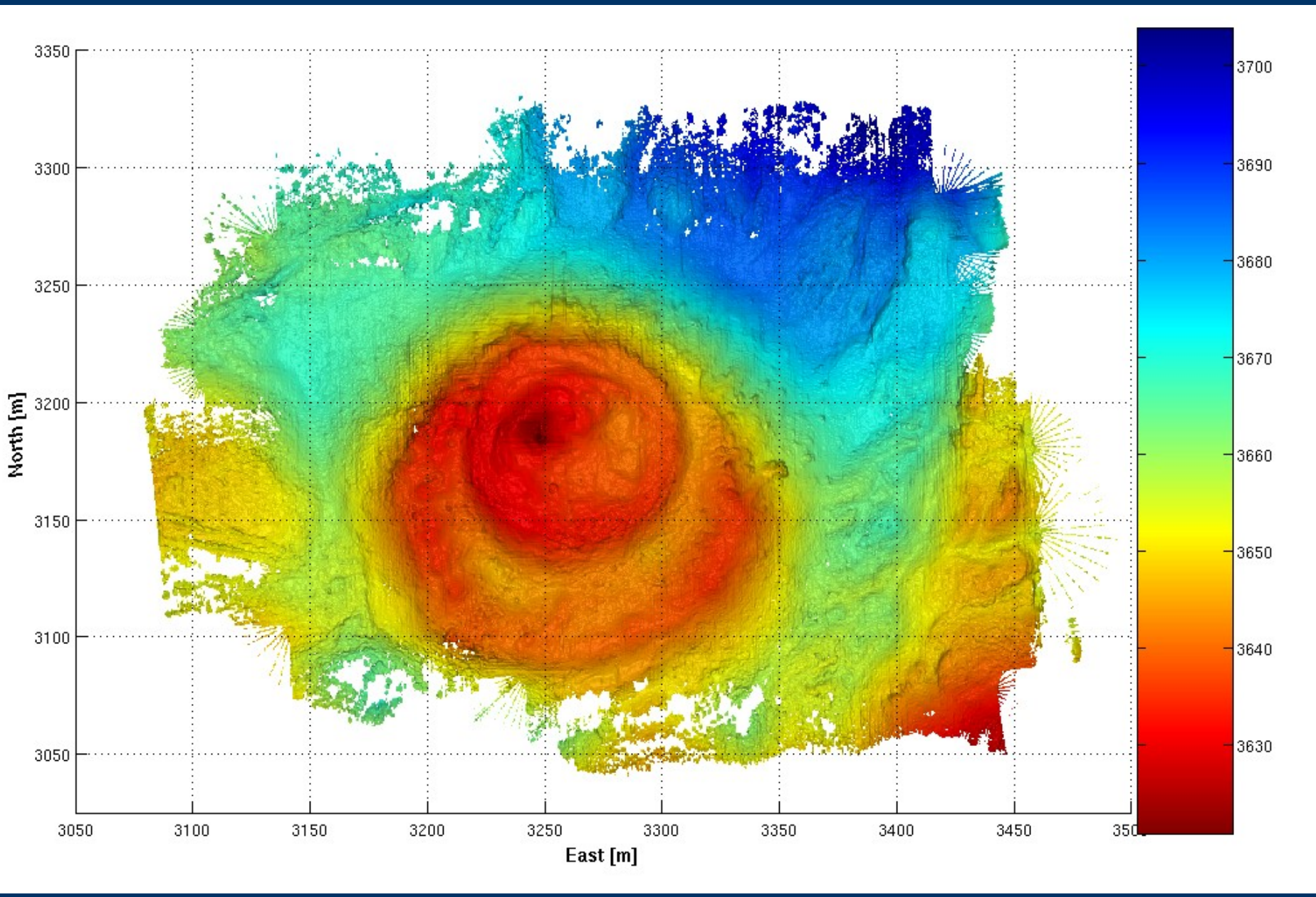
North [m]
East [m]
3350
3300
3250
3200
3150
3100
3050
3050
3100
3150
3200
3250
3300
3350
3400
3450
3700
3690
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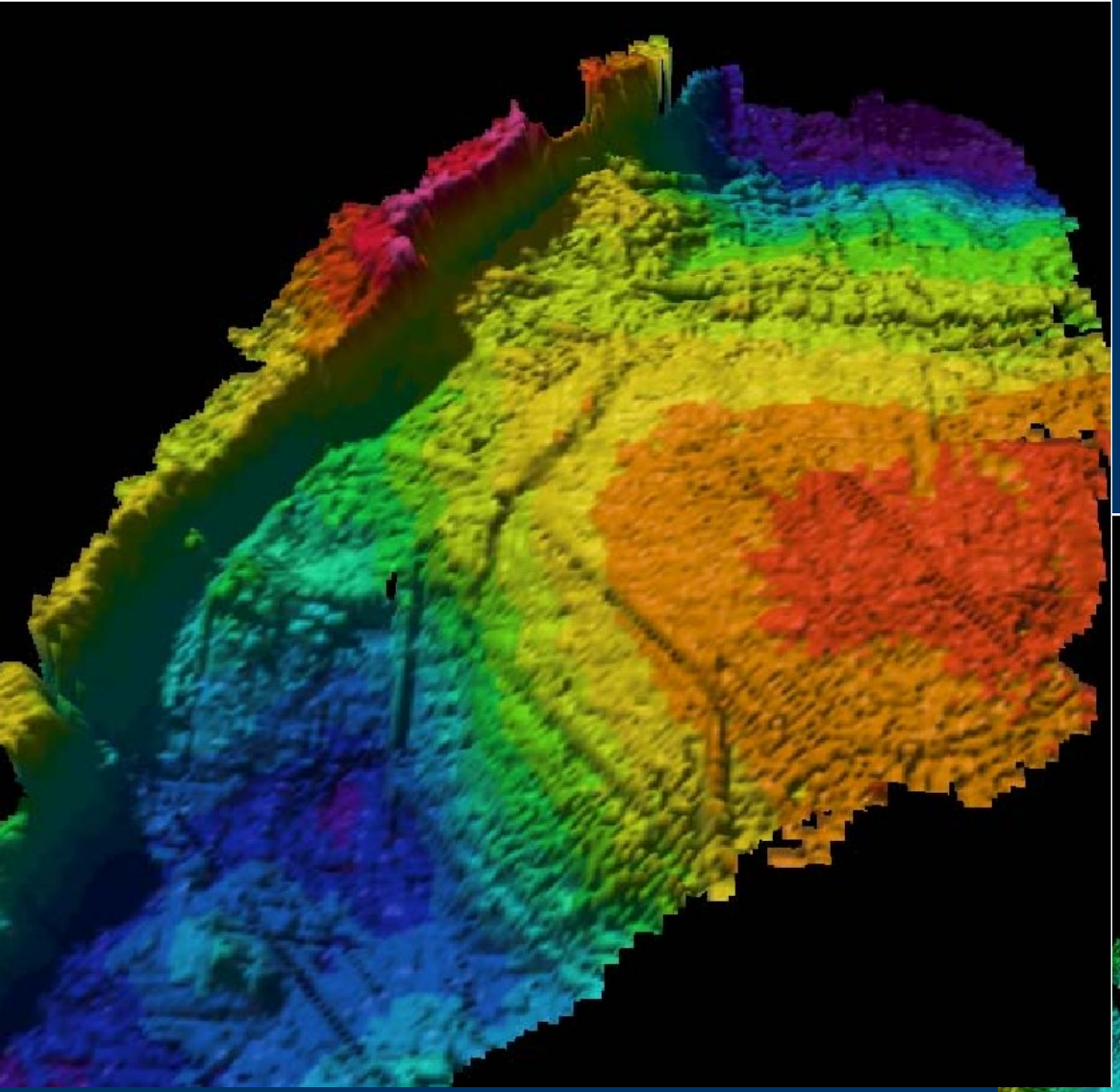
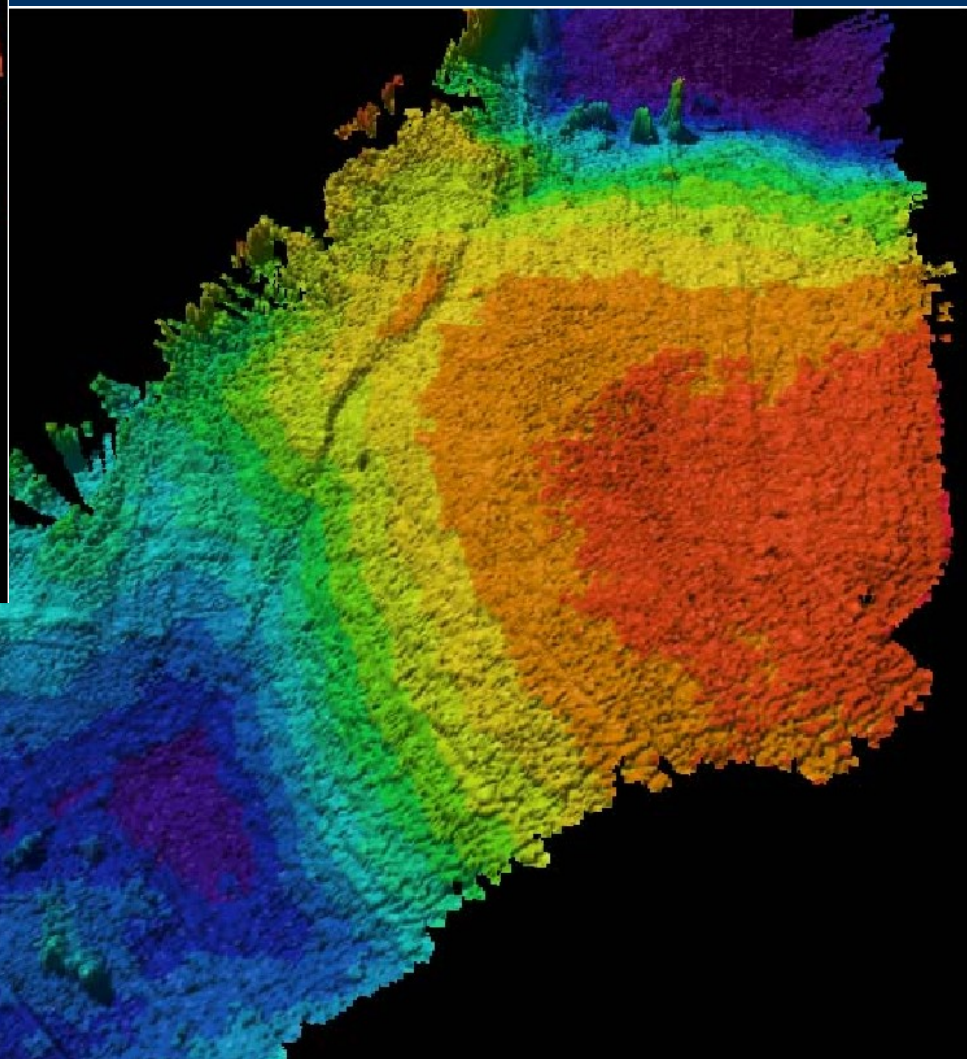
3650
3640
3630



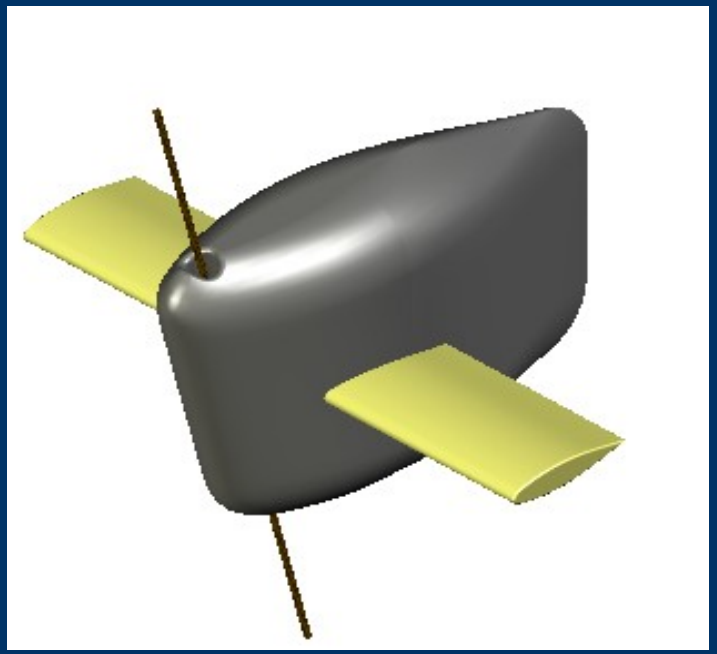


What are vehicles doing next

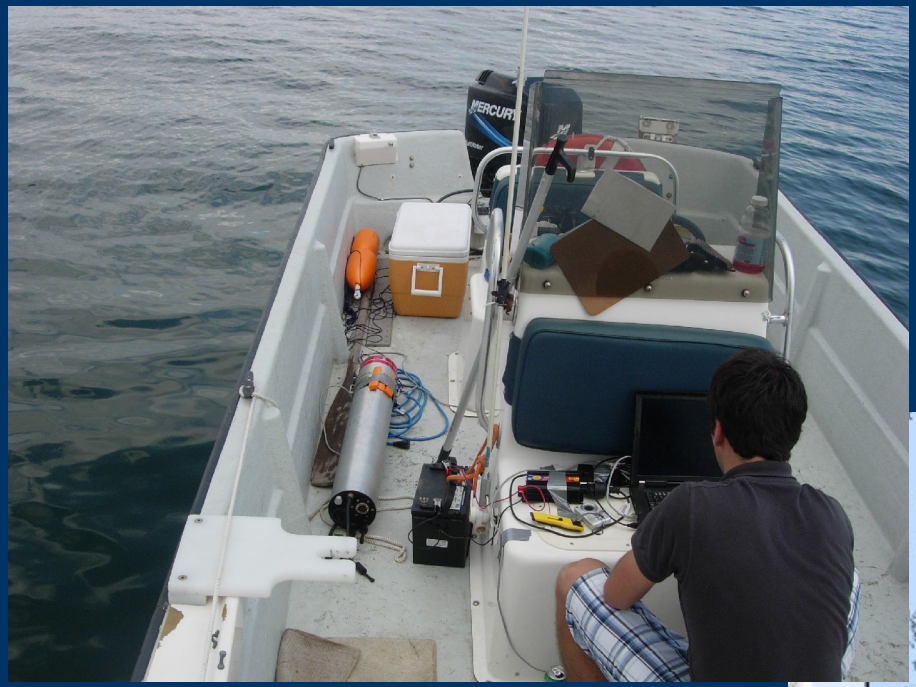
- Arctic Under Ice
- Sample return
  - Gas tight water samples
  - Bringing back stuff
- Smarter real-time algorithms
- Long duration gliders
- Multiple vehicle ops

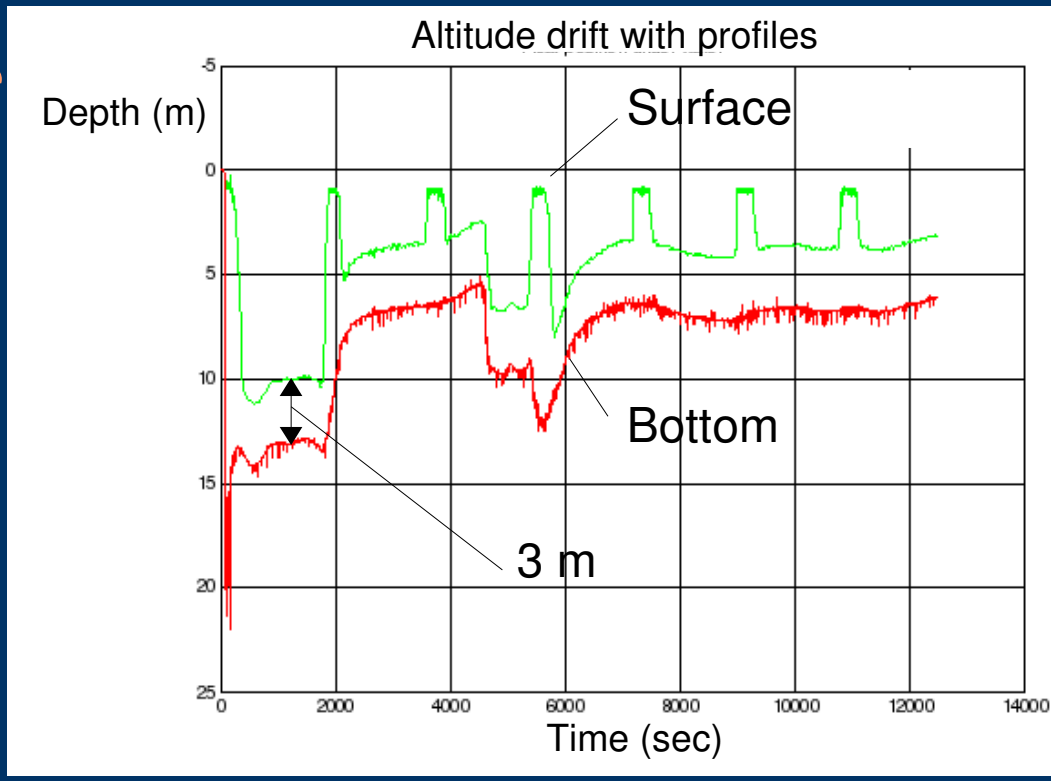
Getting involved

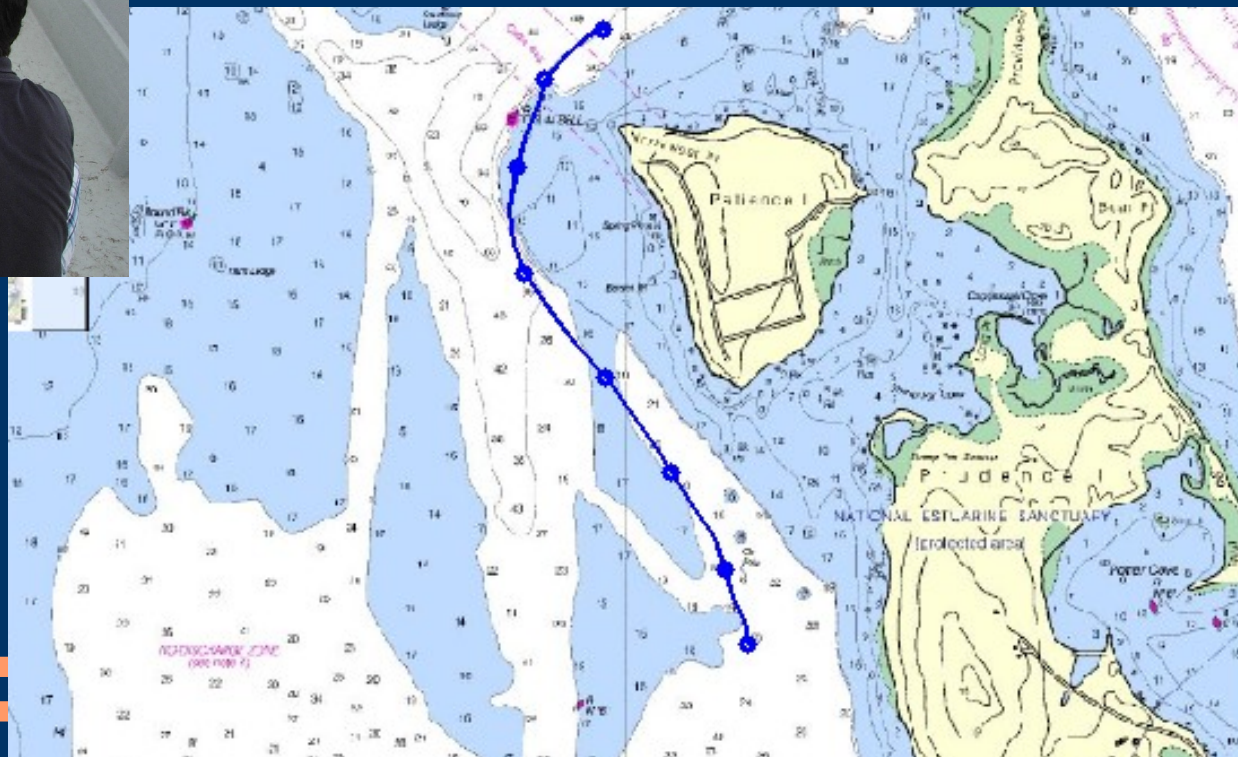
- URI AUV team
  - Professor Tyce
  - http://oce.uri.edu/~auv/
- URI Inner Space Center (ISC)
  - Professor Roman, Dwight Coleman
  - http://oce.uri.edu/~auv/
- Independent studies, special problems
  - OCE 491/492

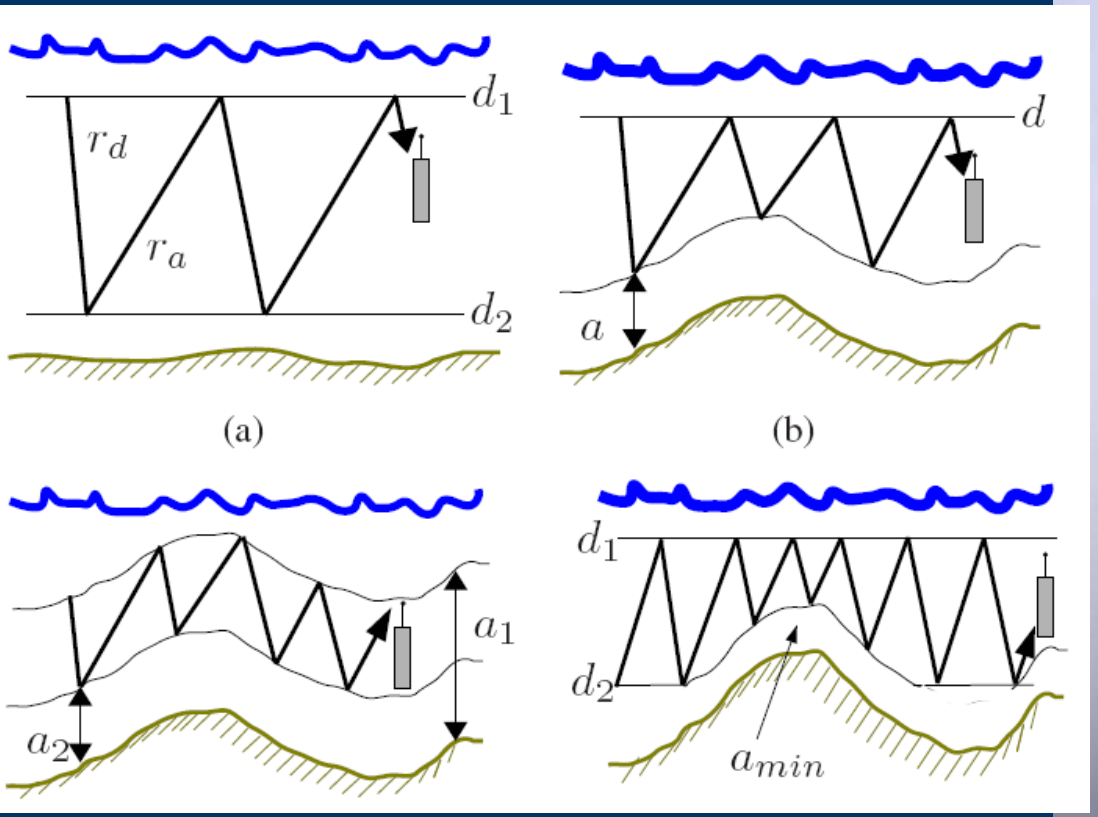


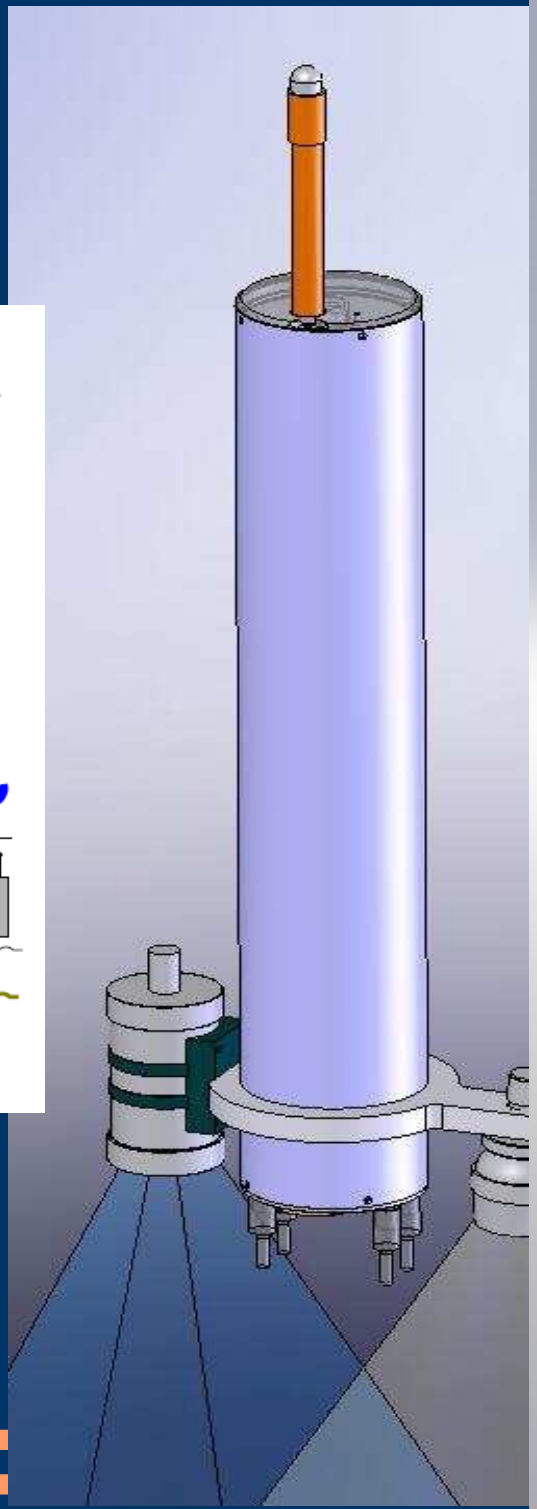
Shallow water floats

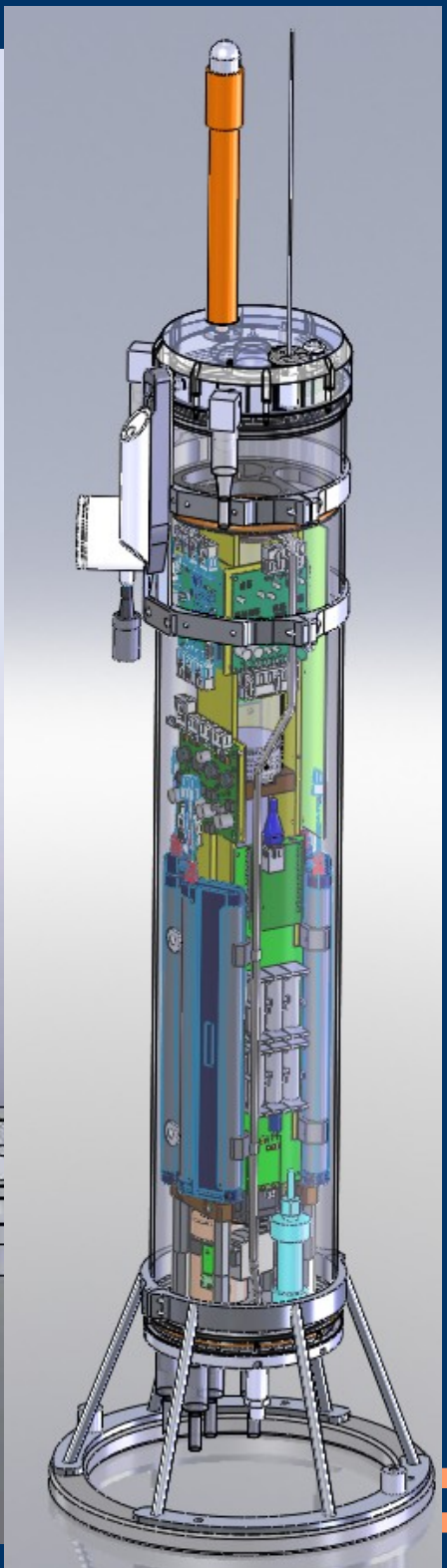







d_1
r_d
r_a
d_2
(a)
d
a
(b)
a_1
a_2
d_1
d_2
a_{min}





The end